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THE INSTITUTE OF PETROLEUM

AN Ordinary General Meeting of the Institute of Petroleum was held at 26 Portland Place, London, W.1, on 21 February 1955, the Chair being taken by the President, Lt.-Col. S. J. M. Auld, O.B.E., M.C., D.Sc.

The Editor read the minutes of the previous meeting, which were confirmed and signed as a correct record.

He also announced the names of members elected since the previous meeting, and gave notice of the date of the next meeting.

The Chairman introduced Mr P. Leicester, who presented the following paper in summary :

THE MODERN PLANNING OF REGIONAL SURVEYS FOR PETROLEUM *

By P. LEICESTER †

SUMMARY

Improved knowledge of the possibilities for oil accumulation has increased the efficiency, and consequently the intensity and cost, of competent exploration. Before a decision is made whether or not to undertake a venture, a geological assessment of the prospects is required, and a preliminary exploration programme and budget should be made for the estimated time required to prove the area. The budget is necessary not only to estimate the discovery risk-money but also to fit into an estimate of the potential profitability if oil should be discovered.

Given adequate financial and technical resources, geographical and geological conditions are usually effectively surmounted; unsuitable working or taxation terms and lack of adequate long-term political stability to ensure a just reward for the large capital investment risked, are the greatest deterrents to oil exploration.

Under usual geological conditions, exploration follows a fairly regular pattern, though it may be difficult to achieve maximum efficiency if the petroleum law restricts the freedom of the operator to concentrate his activity where he considers most expedient.

Some of Shell's prominent present and recent regional ventures are reviewed.

THE search for oil is now a much more complicated task than it was in the early part of the 20th century, when oil exploration was almost exclusively confined to searching at the surface for closed anticlinal structures, situated in the neighbourhood of oil seepages, and drilling into these possible oil traps to depths which were often inadequate to test them thoroughly.

Today greater geological knowledge and the increased depth to which wells can be drilled have opened up many more possibilities for the discovery of oil accumulations. However, only a few, and sometimes none, of these hypothetical possibilities may actually represent the true conditions existing in any particular region, and consequently failure to discover oil is only too frequent.

Efforts directed towards minimizing the risk of missing any economically exploitable oil which may occur, by investigating the much larger number of possibilities of oil occurrence now known, have so greatly increased the cost of efficient regional exploration that only the world's major oil companies, with many irons in the fire, can afford to risk the financial outlay involved in such exploration.

In spite of the increased complexity of exploration and the haste that intensified modern competition has caused, if one had only the problems of inanimate nature to cope with, the planning of modern regional surveys for petroleum in almost any part of the world would be a comparatively simple task for a major oil company.

Even assuming in the first place that the petroleum law in force in the country under consideration offers long-term security and workable terms for both the exploration and exploitation stages, often by far the most difficult task in organizing regional exploration is that of adapting the programme to the limitations and obligations required by the licensing authorities, with the minimum loss of efficiency.

The conditions most affecting the planning of exploration may be summarized as falling into the following categories :

(1) Financial capability of the operating company.

(2) Technical capability of the operating company.

(3) Terms obtainable under the petroleum regulations :

- (*a*) size and form of area obtainable;
- (*b*) duration of tenure;
- (*c*) taxation : royalty, rentals, income tax, customs duty, depletion allowances, and 50–50 net profit sharing basis;
- (*d*) import and export facilities;
- (*e*) foreign exchange facilities; export of earnings;
- (*f*) pipeline and refining conditions.

(4) Long-term political stability.

(5) Geographical and climatic conditions :

- (*a*) accessibility;
- (*b*) communications—harbours, rivers roads, railways, and airfields;
- (*c*) availability of local labour and materials;

* MS received 7 January 1955. † N.V. De Bataafsche Petroleum Maatschappij, Royal Dutch/Shell Group.

(*d*) type of terrain: agricultural, savanna, desert, tropical forests, swamps, off-shore marine areas;

(*e*) temperature: extreme heat, arctic conditions, and, in the case of marine areas, wind;

(*f*) healthiness.

Planning of exploration starts before the decision has been taken whether or not to enter upon the venture, and for this reason it is necessary to deal briefly with the factors leading up to such a decision.

The suggestion to consider the practicability of a venture usually emanates from the geologists, who are continually examining and re-examining available data from all over the world in the light of improved geological knowledge and technical advances.

Occasionally, however, attention may be drawn to an area which has not previously been given a high priority, by some attractive features of a revised petroleum law, which make a venture more secure, profitable, or workable. Sometimes news of success of some competitor, or even merely the interest displayed in a certain region by any of the more reputable operators, may call for a re-examination of the prospects.

GEOLOGICAL CONSIDERATIONS

Requirements for the occurrence of exploitable oil may be summarized as: (*a*) existence of oil which is naturally dependent upon the presence of source rock; (*b*) the occurrence of suitable traps, either structural or stratigraphic, with requisite porosity and within reach of the drill; (*c*) liberation of the oil from the source rock and its migration into the traps, dependent upon permeability and past and present structural conditions and water and gas pressure field; coincidence of source and reservoir rock is a possible case.

In the present state of geological knowledge many of the factors upon which these essential requirements depend, remain unknown until much drilling has been carried out. Thus the geologist of today often finds himself in the position of having to recommend an area when possessing knowledge of only a few of the essential factors, the conjunction of all of which is a requisite for the occurrence of exploitable reserves of oil.

Geologists first try to define areas of possible interest, and then study these one by one from published maps, profiles, stratigraphical columns and descriptions, and the reports compiled from any earlier compilation and reconnaissance.

For each potential region the stratigraphy and tectonics are studied and interpreted to give a picture of:

(1) The thickness of marine sediments. Generally speaking, the thicker the marine sedimentation the greater the likelihood that at some stage or stages conditions have been suitable for the formation of source rock.

(2) The palæogeography, with a view to ascertaining the ancient distribution of land and water at various epochs, and whether past geographical conditions are likely to have been suitable for the formation of oil. Knowledge of where the old shore lines and areas of deepest water lay will indicate probable directions of facies variation and belts in which the relics of certain natural phenomena may be expected, such as old coral reefs and zones where facies changes or transgressive overlap on to the basement may provide stratigraphic trapping.

(3) The facies, in detail where known, in an endeavour to ascertain whether suitable alternations of rock types occur, which are likely to provide source rock, porous and permeable reservoir rock, and impermeable cover or cap rock.

(4) The present-day structure, to elucidate the intensity and direction of past dynamic forces with a view to interpreting the type and trend of possible structures, which would afford suitable traps for any oil which may exist, also the direction and severity of fracturing.

(5) The structural history in order to throw light on the most difficult problem of all, namely migration, whether into adjacent reservoirs or over horizontal or vertical distances. If the date of migration of the oil from source rock could be ascertained, one of the greatest uncertainties in the search for oil would be solved because, if the structure at that time can be inferred, some idea as to the probable direction of migration may be possible.

Determination of the relative age of different folds may occasionally be possible, and past hydraulic movements may in some cases be judged.

Long periods of uplift and erosion (unconformities) are important, as liberation and migration of the oil during or before the unconformity may mean that much, if not all, oil escaped at the surface and has been lost.

GEOLOGICAL CONCLUSION

The opinion regarding the prospects, resulting from the study outlined above, may be expressed as one of quality, but a little thought will reveal that the quality of a prospect must refer to the magnitude of its possibilities. Qualities excellent for the generation, migration, and trapping of a few barrels of oil may be utterly unfavourable for the occurrence of economically exploitable reserves of many millions of barrels.

Thus, factors tending to limit the maximum expectable reserves should be carefully considered, and a rational guess must be made of the expectation.

It is, for instance, obviously not an economic proposition to discover only moderate sized reserves in a region very remote from markets or from the sea or navigable river; a long pipeline may have to be constructed, an expensive item, particularly if it has to traverse mountainous country.

Thus there must be a reasonable chance of the

occurrence of economically exploitable reserves, before the proposition can be considered further.

ECONOMIC CONSIDERATIONS

With discoverable reserves established as a reasonably credible hypothesis, the next stage is to make an exploration programme and budget in order to arrive at an estimate of the "risk" money required for testing the area and for inclusion in a profitability estimate in case exploitable oil is discovered.

This budget, which should be for the estimated number of years it will take to prove the area productive or not, comprises the "risk" money or stake in the bet entered into with nature.

There are two considerations in this exploration, namely:

(1) The risk that the area contains no economically exploitable oil.

(2) The risk that any trapped oil which may exist within the area under investigation cannot be discovered within the limit of capital available for the exploration project; there are obvious limits to the money it is advisable to risk in any one venture.

One of the most ironical circumstances connected with this second risk is that, since in many cases it would take fabulous sums to become 100 per cent certain that no discoverable oil is missed, by defining the barren areas with one's dry holes one has shown any competitor who follows where not to search, with the result that, unless very unfavourable features have been revealed, his chances of finding oil are considerably improved.

In the event of exploration being successful, other risks come into play which, though they may represent smaller chances of loss, nevertheless affect the much larger outlay for development, production, and transport of the oil. Drilling camps, drilling rigs for development of the fields, roads, pipelines, pumping stations, etc., add up to a most formidable capital investment, usually many times that of the original exploration costs.

If the security of this large investment is shaky, and something goes wrong at a late stage of development or during the early stages of production, this is a very serious matter. For this reason, a comparatively small political risk is more serious than a large discovery risk.

Nationalization and adverse revision of taxation are among the worse fears of the oil operator, who naturally wishes to know exactly the terms under which he may exploit his find, if any, before he risks large sums on exploration.

One would not consider gambling at a roulette table if one had the slightest suspicion that the croupier might, at some late stage of play, change the rules of the game or walk off with one's winnings.

The present writer has long pictured the oil business in terms of the well-known "urn of balls" probability model.

Imagine an urn containing many wooden balls and a few metal balls of various values, *e.g.* gold, silver, copper, etc., representing oil reserves of different sizes.

One pays a stake to be allowed to try one's luck. One's technical experts are able to remove a number of the worthless wooden balls, but not all of them, before one makes one's blind pick.

If one is lucky enough to draw a metal ball, one has to pay a further stake many times that of the first to be able to convert the ball into its money value. If there is political risk, an analogy would be that, after paying the large second stake, one had to throw a dice to determine whether one was allowed to keep the metal ball drawn, the valuable ball being confiscated if a specified number or numbers are thrown.

EXPLORATION PROGRAMME

As stated at the beginning of this article, the land and legal situation greatly affects the form of practicable programme.

TYPE OF CONCESSION

The type of concession to be obtained in any specific area may vary according to the stage of development of the oil industry there.

SCATTERED BLOCKS

If the area is proven or semi-proven oil terrain or near producing areas, the authorities may have blocked out the land, and the interest displayed by numerous competitors may have tempted the licensing authorities, or owners as the case may be, to demand stiff fees for acreage.

If such is the case in virgin or only semi-proven territory, much money, which could have been usefully employed in exploration, is lost to the operator. The only compensation to the explorer is that information to be gleaned from neighbouring competitors' unsuccessful and successful wildcat wells may save him the drilling of some dry holes and lead him nearer the pay zones.

The programme over a collection of small blocks may be short and simple, *e.g.* a little gravity, the shooting of a few seismic lines and then deep test drilling, but if the various blocks carry individual drilling obligations or obligatory expenditure which cannot be pooled over the operator's total holdings within the region, a serious misdirection of effort may be unavoidable, *e.g.* geological and geophysical survey may have indicated that concentrated drilling is required in a certain trend to locate, for instance, a reef or zone of stratigraphic traps, or to test a group of structures following various oil migrational possibilities; if such traps can be found, the value of the region will be greatly enhanced, but if the obligations require immediate drilling elsewhere, discovery may be postponed perhaps for several years.

COMPREHENSIVE EXPLORATION CONCESSION

Exploration can be pursued most efficiently where the law allows the holding of large blocks with a free hand as to where the effort is expended; as *quid pro quo* for the authorities, it may perhaps be stipulated that certain percentages of the total original area must be gradually surrendered after specified periods.

However, provided the money may be spent how, when, and where the operator chooses, reasonable obligatory expenditure is not disfavoured as long as he may relinquish his holdings or part thereof with their concomitant obligations, whenever he likes.

On the other hand, obligations requiring equally high expenditure during the first few years of exploration as in the later years, are most objectionable. Such demands for large financial outlay in the stage when normal procedure would be geological and geophysical survey may compel the drilling of wells in unfavourable places, the well locations being based on insufficiently complete evidence.

Given a more or less free hand with the conduct of exploration, its organization is usually a matter of no great difficulty, only needing some modification to suit geographical conditions and some revision to suit the peculiar geological conditions encountered as exploration proceeds.

If the region to be explored is large and difficult of access or is known or suspected of having basement irregularities, the basement configuration may sometimes be most economically revealed by aerial magnetometer survey. This method has greatest application where variation in composition of the crystalline basement or extensive block faulting of the basement renders difficult the correct interpretation of gravity observations without it.

Given normal conditions of basin and shelf and the knowledge that sedimentation is thick, the tools most commonly used are:

(*a*) aerial photography;
(*b*) surface geological survey;
(*c*) gravity survey;
(*d*) seismic survey;
(*e*) core drilling where necessary to reveal facies and structural detail at no great depth, and to yield data useful for improving knowledge of the velocity distribution for better seismic interpretation;
(*f*) test drilling (the boring of wells to test possible producing horizons and to reveal the stratigraphy at depth).

Topographic survey, including the latest electronic methods, palæontological and sedimentary petrological investigations, and the electric logging of coreholes and test wells play an important part throughout exploration.

(*a*) Stereoscopic photogeological interpretation of strips of overlapping photographs, taken vertically from the air, can reveal not only the topography, *e.g.* type of terrain, vegetation, hills, rivers, swamps, paths, etc., but also much of both regional and detailed geological structure. Dip and scarp slopes are often visible where hard bands of rock have resisted erosion, and the trend lines of strike and direction and amount of inclination of the dip can be recorded. Often certain bands or associations of bands of rocks can be followed for long distances and their changes of trend, such as sweeping curves around anticlines and synclines, also sudden breaks or displacements due to faulting, may be mapped rapidly on strips of transparent paper which can be fitted together and retraced to serve as a sufficiently accurate photogeological map, urgently needed for preliminary purposes. More accurate maps corrected for tilt and tied in to base stations on the ground may be prepared in due course.

One of the obvious advantages of aerial photography is that localities of geological interest can be rapidly and comparatively cheaply selected for examination and sampling by geologists in the field.

Before this method was available, geologists might wander for months or years through tropical forests before being able to find and map important structures, which can be seen at a glance from aerial photographs. Trees do not worry the photogeologist to any great extent, usually the trees are of a fairly uniform height, and it makes little difference whether the ground surface is viewed or merely the almost uniform surface of tree tops.

Where no detailed topographical maps are available, even if no surface geological features are apparent, the aerial photographs are invaluable as a basis for preparation of a topographical map, which is needed for deploying the geological and geophysical field parties. In swampy country, for instance, where no firm roads or paths can be made without great cost and delay, much of the gravity and seismic work can be carried out either on rivers or their banks; details of such swampy waterways are seldom shown on available topographic maps.

Important factors affecting the cost of aerial survey are the availability of suitable airfields and the weather. If low clouds are of frequent occurrence, delays may render the undertaking costly.

(*b*) The geological survey parties will naturally be concentrated in zones where surface outcrops can be found or rock may be encountered by digging pits or drilling shallow holes. In areas where the soil cover is thick, the most likely places to encounter outcrops are in shallow stream beds or along the banks of rivers, where the soil has been washed away.

Where no rock is exposed over the whole area of prospective interest, it may still be most useful to send surface geological parties into neighbouring country where exposures may occur (hilly terrain for instance) to examine the facies there and collect samples for palæontological and petrological investigation. Study and sampling of section lines in areas where rock exposures can be found, may serve as a basis for correlation with samples obtained from core drilling and test wells within the area of interest, though, if

the distance apart of exposures and boreholes is considerable, appreciable facies change may be expected.

Geologists will also be required for the interpretation of core drilling and test drilling results and to co-ordinate geological and geophysical data to arrive at a synthetic interpretation.

The geologists' equipment is cheap; a hammer, compass with clinometer, notebooks, acid bottle, magnifying glass, chloroform and filter papers, sample bags and labels, bottles and funnel or drums for collection of gas samples, and perhaps a small stereoscope with a set of aerial photographs. Transport depends upon the nature of the terrain, and may, for instance, consist of elephants, mules, camels, bullock carts, and one or more automobiles. In dense jungle food and equipment may have to be carried by hand; on water a launch, some outboard motorboats with spare outboard motors, and a few dug-out canoes are usually required. Reconnaissance camps may comprise tarpaulins, tents, or huts rapidly built on the spot from local timber or bamboo. The headquarters or base camps may, however, consist of more solid, semi-permanent buildings.

(*c*) Although gravity data cannot yield a unique interpretation, since different density distributions are capable of producing the same gravity field, gravity survey is particularly useful for:

(1) revealing the general configuration of the basement, and thus the relative thickness of sedimentation;

(2) indicating anomalies, the true nature of which may be discovered by seismic survey.

For example, anticlines, elevated blocks, and igneous intrusions usually show up as gravity highs, whereas salt domes and lenses of lighter than average rock usually produce zones of low gravity potential.

From time to time various types of gravity instruments have been popular for oil exploration. Before the construction of such sensitive, yet easily portable and stable, gravimeters as are available today, *e.g.* North American and Worden Gravimeters, various pendulum instruments and the torsion balance have contributed much to exploration.

Organization of a gravity party is simple; transport may be by car, *e.g.* jeep, Land-Rover, or tool car, where roads are plentiful, or by boat, where the rivers are navigable for launches, outboard motors, and other light river craft; through dense tropical forest, the use of helicopters or human transport may be the only practical solution. With a modern gravimeter, the actual gravity observing is a matter of a few minutes per station, the most time-consuming work being the surveying necessary to establish the location and height of the various stations where the gravity measurements are made.

On the whole, gravity survey may be considered a reasonably cheap undertaking and, as previously mentioned, it is of great value as a guide to the most effective deployment of seismic survey. In inaccessible regions camps are usually of the same type as for a geological field party, but where roads are plentiful, the long distances that can be quickly covered may sometimes allow return to base camp or rentable quarters.

(*d*) Seismic survey may be of two types, namely reflection and refraction. Generally speaking, reflection survey is better for elucidating structural detail, but gives one little idea of the nature of the rocks beneath. Refraction survey, on the other hand, may yield a good general picture of the type of rock at depth, and is particularly useful for discovering the depth and general inclination of the basement. For finer detail, however, this method is not only too crude but also too expensive, as it requires the use of very much larger quantities of dynamite than does reflection survey.

Seismic survey on land is not cheap. It requires initially a considerable capital outlay on instruments and transport units, *e.g.* instrument truck, drilling trucks, water trucks to carry water for drilling and shot hole tamping, explosive trucks, trucks for surveyors with their rod men and other labour, and cars for the seismologists and party manager. In jungle, where trucks cannot be used, transport may be manual or by means of helicopters. A central dynamite store with protection against lightning has also to be built, and often a number of smaller portable field storage sheds.

A number of skilled technicians are required: seismologists, operators, computers, surveyors, and drillers, and a large labour force has to be trained to clockwork routine to cover the maximum length of line per day. Rather large base camps are required.

Sometimes several hundred carriers per party are required for daily transport; apart from the cost, the obtaining of such casual labour in underdeveloped and sparsely populated areas may cause a considerable extra burden.

Seismic survey over water is also expensive, but the greater distances which may be covered per day usually render water-borne seismic survey cheaper in the long run than overland seismic survey.

Due to its costliness, seismic survey is primarily a tool for detailing rather than for reconnaissance.

Transport of a seismic team, with its specialized equipment, overseas to the scene of operations, is an expensive exploration item, and it must always be realized that several weeks or even months may be required to organize and train the local labour force, and to experiment in order to determine the best technique to obtain good, usable reflection and refraction records under the local geological conditions. Similarly, some weeks are needed before departure to clean and pack for shipment the considerable quantities of equipment used.

A seismic party needs to be a friendly, co-operative team if maximum efficiency is to be attained. A staff problem is to know when to keep the most efficient teams as unchanged compact units or whether to try to raise the standard of other less efficient parties by salting them with the men from the better teams.

(*e*) For core drilling campaigns, the most important factor is choice of a suitable rig for the geographical and geological conditions. Where plentiful roads exist or in motorable savanna or desert country, truck-mounted drills can be used, but in jungle and swamp, lightness and portability of the equipment is of primary concern; transport along waterways may be the solution in deltas and other swampy terrain.

(*f*) Preparations for deep test drilling are beyond the scope of this article, but, during the preliminary survey, attention should be paid to such matters as:

(1) harbour loading and unloading facilities;
(2) storage space;
(3) roads and bridges which may have to be built or modified to carry the heavy loads of drilling equipment and allow the passage of long lengths of pipe;
(4) water supply;
(5) building materials, etc.

Radio communication between parties and field headquarters has proved of great benefit in all stages of regional surveys.

FEATURES OF SOME OF SHELL'S REGIONAL SURVEYS

Ecuador

The exploration carried out by Shell between 1938 and 1950 for her joint venture with Standard Oil Co. of New Jersey, east of the Andes in Ecuador, though unsuccessful, provides a romantic epic of great difficulties surmounted, and it was the first large 100 per cent airborne operation of its kind in the history of the oil industry.* The cost was of the order of $30,000,000.

The methods of survey may be briefly summarized as follows:

An aerial photographic survey was carried out by Fairchild Aerial Survey Inc. over about 13,000 sq. miles across the foothills and part of the Central Orient. A net of astronomical stations was used to tie up both the aerial survey and the geological and geophysical surveys which were carried out beyond the limits of the area photographed.

Geological surveys were carried out in the Western Orient and along the larger rivers of the Eastern Orient. Simultaneously gravimetric survey successively with Holweck pendulum (232 stations), Thyssen gravimeter (4321 stations), and La Coste gravimeter (1751 stations) over the whole concession of 32,792 sq. miles. In the strongly folded sub-Andean zone the gravity data reflected the structural features, but it was found that in the Eastern Orient the gravity anomalies were largely influenced by deep basement masses and that the slight folding of the cretaceous and tertiary there did not show up clearly on the gravity picture.

When this state of affairs became apparent, the gravity survey was abandoned and seismic survey was started. From July 1943 to August 1949 nearly 2000 miles of seismic reflection lines were shot in the Orient, using two parties most of the time. During this survey, supplies of food and equipment were dropped to the parties by parachute.

A base camp, "Shell Mera," with a landing strip was constructed in 1938 at the eastern border of the Andean foothills. One of the most costly features of this Ecuadorian venture was the construction of six airfields, namely, the one at Shell Mera and one at each of five of the six structures drilled.

In all, six deep tests were drilled, two, namely, Vuano (total depth 5280 ft) and Oglan (9438 ft), were situated about 5 miles apart in the foothill area to the west, Villano (10,889 ft) was located farther out into the basin, some 25 miles SSE. of the Oglan well. About 70 miles and 100 miles respectively south of the Vuano well lay the Macuma (7016 ft) and Cangaime (3542 ft) wells. Far over on the eastern part of the basin the Tiputini well (5592 ft) was drilled at a locality on the left bank of the Rio Napo some 150 miles ENE. of the Vuano well.

This venture is remarkable for the circumstance that each of the six test wells had oil shows of a few barrels of heavy oil or tar but no economic production, thus encouraging further search and consequently more expenditure. Opinion as to the cause of this phenomenon varies from the hypothesis that no adequate source rock is present to the theory that oil once existed in quantity but escaped during one of the erosional periods evidenced by known angular unconformities.

Netherlands New Guinea

The first geological reconnaissance by the Bataafsche Petroleum Maatschappij (B.P.M.) of the Royal Dutch/Shell Group was in 1905, but thorough exploration of this wild and inaccessible country did not start until 1930 in the West Vogelkop region. Based on this second reconnaissance, the Nederlandsche Nieuw Guineee Petroleum Maatschappij (N.N.G.P.M.) was formed in 1935 as a joint venture of the B.P.M. (40 per cent), the Standard Vacuum Oil Co. (40 per cent), and Far Pacific Investments Inc. (20 per cent).

Aerial mapping was started over about 39,000 sq. miles of dense tropical jungle, and geological survey parties commenced operations using as a basis the photogeological maps compiled from the aerial photographic survey.

In 1936 gravity survey started with Holweck pendulum surveys, and continued in 1938 with Thyssen gravimeters; more recent gravity survey has been carried out with North American and Worden gravimeters.

Magnetometric trial sections were made in the Vogelkop area as early as 1938; recently great tracts (65,000 sq. miles) have been covered in another part

* Tschopp, H. J. *Bull. Amer. Assoc. Petrol. Geol.*, 1953, **37** (10), 2303–47.

of New Guinea by air-borne magnetometer survey of Hunting Geophysics Ltd.

Seismic survey began in 1938 with three parties, and has continued in New Guinea ever since, except for an interruption during 1942–48, due to the war and immediate post-war conditions.

Recently the use of helicopters has greatly assisted progress of seismic survey; clearings of only 300 by 90 ft in the jungle are adequate for landing, 20 by 20 ft of which must be smoothly levelled.

By the end of 1941, besides some 65,000 ft of geological structure drilling, thirty-three test wells had been drilled, the deepest of which was 9840 ft.

The first test well in New Guinea was spudded in on 30 May 1936, on a NE.–SW. trending structural

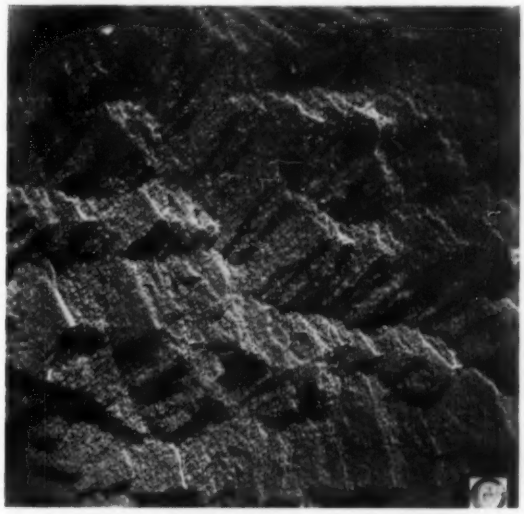

FIG 1

AERIAL PHOTOGRAPH OF NEW GUINEA JUNGLE

high near the western end of the Vogelkop. Oil was struck between 426 and 502 ft in the top of a Miocene coral reef limestone, capped by the Miocene marls, on what is now the Klamono oilfield. The daily production in 1954 was 4800 brl of asphaltic, 0·94 gravity (19° API) oil from twenty-one wells, the cumulative production to 1 January 1954 being 8,865,894 brl. The oil is pumped 30 miles through an 8-inch diameter pipeline to the harbour of Sorong.

The first well on the Wasian structure in the south-eastern part of the Vogelkop, spudded in in February 1939, 138 miles southeast of Klamono, was also a discovery well. Production was encountered in the top of the oil-bearing limestone at 2952 ft, and the well was carried down to 8810 ft.

During 1940–41, five wells drilled on the Mogoi structure some 8 miles west of the Wasian field started to prove what is now the Mogoi oilfield.

Outlet to the sea from these fields is by a 30 mile-long pipeline to Steenkool on the Gulf of MacCluer, which was opened in 1954.

Unlike the Klamono oil, that of the Wasian and Mogoi oilfields is of paraffinic base with gravities 0·784 (49° API) and 0·804 (44·5° API) respectively.

Although drilling in the Vogelkop of Netherlands New Guinea met with unusually early success, the fields so far discovered are small, and the search for further fields is arduous. Enormous Miocene reef bodies exist in this area, but, alas, the largest has no cover rock, and millions of tons of oil which may once have lain in these excellent reef reservoirs must have gone to waste millions of years ago.

Canada

Shell's first exploration in western Canada was of regional character, being mainly concentrated in areas where large acreage was available for reservation. In general the programme comprised gravity survey accompanied and followed by much costly seismic survey over large areas, and included substantial wildcat drilling.

A simultaneous programme was concentrated in the most prolific reef region yet discovered in Canada, where land becomes available from time to time according to the Alberta regulations. These regulations demand return to the State of 50 per cent of the licensed acreage after a limited number of years. The State then offers the freed terrain for bidding by sealed tender.

Consequently, the tendency is for the proven and semi-proven areas to become divided into small blocks, which, though attractive in themselves, render less easy the economically efficient operation of large operations.

Heavy obligations on individual blocks often decrease the efficiency of exploration by necessitating drilling in specific areas before exploration has revealed the true geological picture of the region.

Of practical interest affecting test drilling in northern Alberta, northern British Columbia, and the North West Territory are the muskeg * swamps, where the ground is only firm enough in winter to support a heavy drilling rig; here the erection, drilling, and removal of the rig must take place within four months (from the beginning of December to the end of March) under the most trying conditions of cold.

French North Africa

Shell is engaged upon regional exploration on a large scale in French North Africa. In Tunisia, Compagnie des Pétroles de Tunisie (C.P.D.T.), a joint venture with the French company Société de Recherches et d'Exploitation des Pétroles en Tunisie (S.E.R.E.P.T.), on a 65 per cent Shell, 35 per cent S.E.R.E.P.T. basis, with Shell as technical managers, began exploration over 5850 sq. miles in 1949.

* Muskeg is water-soaked decayed moss and dead trees, often of great thickness.

Methods applied so far include photogeological interpretation of existing aerial photographs, geological, gravimetric and seismic surveys, and core drilling. At the time of writing, four test wells have been drilled with a heavy rig, and a fifth well is nearing completion; two wells have been completed with a medium capacity rig, and a third is drilling.

FIG 2

AERIAL PHOTOGRAPH OF AN ANTICLINE IN THE SAHARA

More remarkable for the size of the undertaking and the difficulties of remoteness and climate is Shell's Algerian Sahara venture (Compagnie des Pétroles d'Algérie, 65 per cent Shell, 35 per cent French interests). The concession of 61,660 sq. miles lies in the Saharan desert between 500 and 700 miles from the Mediterranean coast. In addition, Shell also has a share in a French managed venture of Compagnie de Recherches et d'Exploration de Pétrole au Sahara (C.R.E.P.S.) lying immediately south of the above-mentioned area.

Very long communication lines across the desert cause high transport costs; supplementary air transport used has necessitated the preparation of a number of landing strips.

The whole concession was aerially photographed, and photogeological interpretation of these photographs is still in progress.

Field surveys have called for the use of a few geological field parties, numerous gravity parties, a few seismic parties, and a deep core drilling party.

The first test well was drilled to 7197 ft, and a second well was spudded in recently. In the area of C.R.E.P.S. to the south the first exploration well encountered dry gas in substantial quantity, and the drilling of two further exploration wells is in progress.

Field work is not practicable during the hottest months (June to September inclusive), but due to air-conditioned quarters and special cooling methods on the rig, it was possible to continue drilling through the summer.

Nigeria

The venture of Shell/D'Arcy Petroleum Development Co. of Nigeria involves an equal participation of Shell and the British Petroleum Co., with Shell having the technical management.

Work started in 1937 with geological reconnaissance. More detailed geological survey followed, supplemented by core drilling. Later, gravity and seismic reflection and refraction surveys were started, but suspended from 1941 to 1946 due to the war.

After 1946 the intensity of exploration was stepped up. Intensive aerial photography has yielded maps of great value to the country, particularly those of the hitherto but little surveyed delta area.

At the time of writing, the one remaining geological party has almost completed the necessary surface geological observations, gravity survey has been completed, and a number of seismic parties are at work, one of which is a marine-type cable party which works in the delta.

Core drilling parties have been active, one of which is at present engaged on the testing of appraisal wells on the first discovery.

So far, two rigs have completed five deep tests, two of which yielded oil and gas and a third gas only. Two new wells are now drilling. A contract string has completed one appraisal well, and is drilling a second.

FIG 3

DRILLING UNDER TYPICAL CANADIAN WINTER CONDITIONS

Three helicopters are being used for transport of personnel and urgent supplies, of which two at a time are in daily use.

Several existing bridges had to be strengthened to carry the heavy drilling components.

DISCUSSION

D. C. Ion: I believe, as did my late chief, Dr G. M. Lees, that regional surveys are the foundation of the oil business, and it is right that Mr Leicester should stress both the economic and geological aspects of the modern planning of regional surveys. On the economic side, his point, about the enormous amount of risk money now required for exploration, is stressed by the tendency for the combination of financial resources. Major companies combine not only together, but also with local private enterprise; an example of the latter is the combination of the Gulf and the Montecatini interests which is responsible for the new discovery in the Abruzzi, Italy. Independents also combine with each other, *e.g.* the syndicates now working in Spain, Somalia, the Kuwait Neutral Zone, and so on. The practice in Canada follows closely that of the U.S.A., where the sharing of the risks of wildcatting has long been common. This tendency to combine is one which must increase as the cost of exploration rises.

On the legal side, most people are familiar with the witch hunt against restrictive practices (which can be a dougle-edged weapon), and I therefore strongly support Mr Leicester in stressing the importance of reasonable laws. One cannot too often try to explain to governments, and to the innumerable international bodies who try to interfere in commercial dealings, that conditions which prohibit the free employment of risk capital are indeed restrictive. The primary gamble is with Mother Nature, and if countries prevent it by not permitting a reasonable return for a success, they fail to benefit themselves. The most glaring example is the bulk of South America. Much oil there will stay in the ground and the countries will not benefit from their resources unless conditions for capital entry are ameliorated.

In regard to the geological side, Mr Leicester mentioned the need for an early appreciation of the possible quantity of oil likely to be found. There is yet another link between economics and geology in the quality of the crude oil itself.

At the present time, the proved reserves of the world are such that if oil was produced at the maximum efficient rate the world demand could not absorb it all. The quality of oil becomes, therefore, increasingly important.

Probably more nonsense is talked and thought about the quality of crude oil than about most other things. The appreciation of quality depends entirely on what is wanted from the oil. In 1900, the demand was for lamp oil only; later, it was for straight-run benzine, higher octane motor spirit, and aviation spirit; then middle distillates for diesels; and now, particularly in the Eastern Hemisphere, for fuel oil in increasing quantities.

As the market demand for the different fractions manufactured from the crude varies, so does the appreciation of what is the "best crude." Yet, because of this continuously changing pattern of market requirements and because of the individual needs of different companies to meet their own special or peculiar outlets, the quality of the oil is a most important economic factor. The forecasting of quality of crude is therefore as important as forecasting quantity, and though as yet quality forecasting is based on even more slender principles than quantity forecasting, yet the regional approach is again the only sure approach, and I am never tired of saying, as I am sure Mr Leicester will agree, that the geologist must be the leader in the team of chemists and physicists who are tackling the problem.

Turning now to the detail of the planning I would like briefly to mention four points:

(1) There can be no doubt as to the advisability of continuous world-wide consideration of all areas, for as Mr Leicester says, new facts call for constant revision of opinions as to prospects. It is only large organizations, either oil companies or consultant firms, which can afford such constant employment of research geologists on such tasks. Even in large oil companies the snag is that it is far easier to obtain an appropriation of funds for an area during a hot "oil rush" than when the area is cold, and sound positive regional considerations the only argument. The sheeplike herd instinct of oil companies is most marked: Rumania was, Australia is a wonderful example, Canada is another, and none is better than the U.S.A.

(2) My geophysical colleagues will feel that the author dismisses too cursorily the usefulness of the refraction method of seismic survey, for in some places this is the only method which gives any interpretable results, and these are often of great value.

(3) Mr Leicester refers to geophysical marine work, but not geological submarine work employing the aqualung method. This can be most useful in special circumstances, such as those employed by the British Petroleum Co. in the Persian Gulf in 1954.

(4) Mr Leicester's mention of the many aspects in which the geologist helps in a regional survey require emphasis. Aerial photography and photo-geological mapping in an office may have taken away much of the high adventure from reconnaissance geological mapping in unknown country; accurate measurement of imperfectly understood physical phenomena may, by its greater cost, have elevated geophysical surveys to a greater importance in the minds of some, yet the leadership by the geologist of the growing team of specialists now employed on regional surveys is all the more vital to the efficiency of, and balanced results from, these surveys.

P. Leicester: In connexion with choice and chance, Mr Ion mentioned the quality of the oil. Of course, if one is in an area which the oil industry has developed to a certain degree, then one usually knows quite a bit, but in the early stages of many of these regional surveys, one often knows very little. I think the principle to go on is (on a probability basis) to assume that the oil is all right unless you know that there is something wrong with it, and I expect that if there is something wrong, there is usually some indication somewhere in the neighbourhood; there may be seepages, or there may be production that leads one to fear that the oil is not good. I feel that, in making an estimate or choice, unless one has had evidence that the quality of the oil is likely to be poor, one should assume that it is going to be reasonably good.

I do not know much about refining, but it is wonderful what the refiner can do. One might take it this way: that perhaps the quality of oil, unless there is something very much wrong with it, is not quite so important as it might appear, because the refiner can help you out. Good refining technique widens the class of oil that may be considered reasonably good.

The other point Mr Ion raised was about refraction. I would like to mention that I am not at all against refraction—I am a great supporter of it. In section (*d*), p. 221, I mention that seismic survey may be of two types, namely reflection and refraction. Generally speaking, reflection survey is better for elucidating structural details, but it gives one little idea of the rocks beneath. Refraction survey, on the other hand, may yield a good general picture of the type of rock at depth, and it is particularly useful for discovering the depth and general inclination of the basement. For finer details, however, this method is not only too crude but also too expensive, as it requires the use of very much larger quantities of dynamite than does reflection survey. Thus, the two

should be combined: refraction to get a good general picture of the basement and its general inclination, and reflection for working out the details of structure.

The other point is that, in so far as I know, British Petroleum have been first in the field with submarine geological work. Although oil companies do not always tell each other what their results are, I agree with Mr Ion that greater attention should be given to submarine geology.

P. Evans: Sometimes, it seems as if the refining side, that makes the products which bring in the revenue, is thought more important than the exploratory side which spends so much money. It is extremely useful for all sides of the industry to have a picture of what the other man is doing. For those concerned with exploration, perhaps more particularly the geologists and geophysicists, it is a very good thing for the hazards of a non-geological nature to be emphasized. One thinks of the chances of oil or gas in this or that structure or this and that region, and once it has been decided that there is a good prospect or a poor prospect of getting oil, one may feel there is no further work to be done. But it is well to have one's attention drawn to all these other hazards that geologists certainly should be aware of, and Mr Leicester has had particularly good opportunities of getting to know the nature of the political hazard, if I may call it such, since he has seen it from both sides. Before coming to the oil industry he had a long experience in the Geological Survey of India, and was able to look at the problem from the government's point of view. Now he is able to look at it from the operator's point of view, and the result is that he can give us a balanced account of the difficulties of a political and economic nature that confront a company anxious to explore for oil.

Mr Leicester rightly emphasized the need for looking ahead and referred to the changes in budget necessary as new evidence, whether favourable or unfavourable, comes along, mentioning particularly the enormous amount of capital required for successful exploration. Unsuccessful exploration is usually reasonably cheap, but successful exploration is an expensive affair.

I support Mr Ion's view that the geologist should be the leader in this composite team of scientists concerned with exploration; it is the geologist's job to be their interpreter, and to explain to those responsible for deciding the company's policy what the team as a whole, and particularly the geologist leader of the team, thinks that the evidence adds up to.

P. Leicester: The geologist in all companies should be in close contact with the people who, at a high level, are planning the strategy of any company. Imagine how difficult it would be if one had to play roulette, and the chap with the money got up just at the critical moment and said "I am sorry, I must go. I shall spend the money on something else." It might upset one's plans considerably. The petroleum industry is somewhat similar to insurance in reverse. Whereas an insurance company is charging a premium against a risk, the petroleum industry is paying for the desired reward. It must therefore have a clear idea of the risks and possible rewards and thus the expectations associated with alternative plans for investment in exploration.

A. E. Gunther: In speaking of air transport, Mr Leicester mentioned helicopters in the exploration of New Guinea. In one or two exploration areas, for instance in Borneo, conventional means of air transport supply geological parties in the field. It would be interesting to know the logistics which underlie these two methods.

Since by air men may move to and from the less easily accessible areas in an hour or two, instead of several days or even a couple of weeks by land and water, can Mr Leicester say how long the geologist or geophysicist spends in the field before returning to headquarters?

P. Leicester: In regard to helicopters and ordinary aeroplanes. Oviously, aeroplanes are needed where heavy loads have to be carried to a central supply base. If the exploration of poorly accessible terrain is anything more than a reconnaissance, it is expedient to make a flying strip at a convenient base, but for seismic and gravity survey, where one is just hopping around the area and where no big centre of activity is likely to develop unless one finds something interesting, then it is obviously better to use helicopters and make only small clearings. Our Ecuadorian drilling project necessitated six flying fields—that was rather costly. Supplies were dropped to the gravity and seismic parties by parachute. At present, whenever practicable clearings are made and helicopters used. Helicopters may even be employed to transport certain drilling equipment, sawn up into convenient pieces and welded together on the spot. The general answer to the question is: where much material is to be moved, a landing strip; where great mobility is needed, helicopters, but mostly the two together.

In regard to the second part of the question, the periods spent by geologists and geophysicists at any one location are decreasing, though the duration of the stay naturally varies with the locality and the nature of the work.

In Nigeria, for instance, the maximum period usually spent in the field at any one time is six weeks, and after each such period there follows a week or more at the base.

In Borneo the maximum stretch is two months followed by one or two weeks at local headquarters.

In Netherlands New Guinea, seismologists are usually about six weeks at a time in the field with intervening periods from six to ten days at the base. In the case, however, of field-geological survey in remote areas, the party usually completes the survey in one operation lasting, say, from three to five months, and then packs up and returns to the base for a considerable period to compile the reports and maps.

Naturally, all parties spend several weeks at the local headquarters when the time comes for them to complete a report on one of their surveys.

Professor S. E. Hollingworth: In view of the rapid development of exploration techniques and the speed of movement, there is not an equivalent speed of promotion. Are not important positions held by comparatively young men?

P. Leicester: It is naturally difficult to lay down any hard and fast principles governing promotion of staff to executive positions; in fact, no rules should be made.

Promotion into administration naturally depends upon the capabilities of the individual and the staff requirements from time to time. Generally speaking, however, a good man, who has proved to be efficient both in the field and later also in the office, should be in line for a job as area chief geologist or area chief geophysicist after about ten years of service with the Group.

Lt.-Col. S. J. M. Auld: Can the layman be given an idea of the proportion of successes before and after the development of modern methods and modern organization. Does one, in fact, get a greater number of positive results now than in the past, or is the task still dependent on factors beyond forecast?

Mr Ion referred to the quality of the oil expected to be found. I know of few fields where the discovery of oil has not been welcomed so long as it is capable of being brought to the surface. In these days of extensive refining treatments, it seems to me that the most desirable feature of the crude oil is its ability to flow. However, I appreciate Mr Ion's point that it is another risk factor and risk expenditure is pretty high already.

P. Leicester: The President has certainly raised a most interesting point which has been in mind for some considerable time. One must be very careful from a logical standpoint in applying a success ratio from one area to another. I do not claim to be an expert on it, but I think if one uses the success ratio of one geological province as a guide to one's chances in another, it is rather like saying "We have found that the chance of drawing two aces from a pack of fifty-two cards is $4/52 \times 3/51$; and we will now associate the ratio also with a pack of thirty-two cards." There are other ways of tackling this problem, but the point that the President raised was: "How has the success ratio varied with time?" It would be very interesting if a member of the Institute could collect some statistics on this, because there are two contrary trends. One of them is that we know now that oil can occur in a great many more different types of trap than had been thought of before. The other is that these more recently realized possibilities are very much more difficult to find, so that a lot of time is spent in looking for things that would never have been thought of in former days.

Therefore, very broadly, when in the past one looked only for accumulations in the most obvious places, one had rather better chances of early discovery, whereas now one is gradually including objectives that are difficult to find. Thus, the present problem is: If unknown exploitable oil accumulations exist within an area under exploration, can one find them within the capital that it is wise to spend on such speculative search? I pointed out in the paper the irony of failing to discover oil. Each time this happens one has improved one's competitors' chances. With the modern trend of looking for the more unusual accumulation phenomena in the hope of not missing anything, exploration is a much more risky business now than it was in the not very distant past. I feel, however, that the Institute could perform a considerable service to the industry by persuading those interested in this question to collect the necessary statistics. One always looks with the greatest interest at U.S. statistics, and it would be invaluable if similar ones were compiled for the rest of the world.

As regards the quality of the crude, I do not feel that the risk is a very serious one. The geologist should be thankful if oil is found in quantity.

D. C. Ion: I certainly think it is serious. The refiner is not necessarily happy to produce what the market wants from the stuff which has been given to him. I made the point about the quality for two reasons: First, there is the quality, as well as the quantity problem; and, secondly, that it is not a problem that should be left in the hands of chemists or even physicists, but one upon which there is a tremendous amount of research work that the geologist, with his knowledge of the earth, can sew into this problem. This is a problem that should not be thrown away on the idea that somebody else will answer it.

P. Leicester: Mr Ion has certainly raised another interesting point, but I am wondering how the geologist is going to set about it. Is Mr Ion suggesting that from a study of the facies, the geologist may be able to get some idea of the quality of the oil, or is he thinking of developed areas where people certainly pay a great deal of attention to quality? In such areas one moves away from the bad quality and searches elsewhere. Supposing one is appraising an unexplored area, and one does not know anything about quality except from an analysis of a seepage; if there is nothing wrong with that, is Mr Ion suggesting that the geologist might be able to do something more about forecasting the quality of oil in hypothetical accumulations?

D. C. Ion: I am, yes. The study of that oil which has been discovered, and the variations in those oils in the known areas, is possible and I consider that the geologists should help towards forecasting what the quality of the oil might be in an area that is otherwise unknown. I do not see why it should be an impossible problem.

P. Leicester: No, but is not that very much of a statistical correlation problem? I think that statistical methods are going to play an ever increasing part in the oil industry. All inexact sciences have to rely for the unobservable on the result of the examination of large numbers of samples and subsequent correlation. Might one say that Mr Ion recommends correlation between quality and facies as a statistical study for the benefit of geologists?

D. C. Ion: Yes.

P. Leicester: That is entirely my view, because I am somewhat of a cynic about the possibility of drawing any hard and fast conclusions from uncertain hypotheses. It is very instructive to follow the changing fashions of oil geological reasoning and exploration effort. I often feel that one must maintain a cautious attitude towards excessively speculative academic geological reasoning, which can lead an operator so beautifully up the garden path to empty his pockets on some hypothesis that may be completely fallacious, and therefore I appeal to statistics wherever they can be used. Nevertheless, vivid imagination is necessary to enable the various alternative interpretations, and thus possibilities to be visualized. Correct assessment of the relative probabilities of the alternative possibilities is the important point!

A. E. Gunther: Some corrective should surely be given to Mr Leicester's reply. It is known that the U.S. "success ratio" figures present a more favourable picture:

Non-technical (wildcat) . .	1 : 30
Geological	1 : 10
Geophysical	1 : 6
Geological and geophysical .	1 : 5

If success ratios were available, for instance, from the Middle East the figures would make a better showing still, and would provide a wonderful example of the application of modern technical methods to aid exploration.

P. Leicester: I do not appear to have made my point clear. Naturally, greater geological knowledge and improved methods of search have increased the efficiency of exploration, but, with increasing scarcity of easily discoverable accumulations, we are gradually being forced to explore areas which appear *a priori* to be less promising.

The increased risk is only partly a result of the difficulty of locating traps, and much of it is owing to the increasing dearth of areas having obviously encouraging geological features, which circumstance leads exploration into more speculative ventures than would have been considered warranted in the past.

N. L. Falcon: May I refer to a point which tends to be forgotten when considering the value of figures obtained by calculating success ratios for exploration boreholes? This is that it is rarely possible to assess accurately the proportions of the contributions made by geology, geophysics, intuition, or pure hunch in selecting an individual location. Furthermore, no rigid distinction is possible between exploration and step-out wells. Everyone, diviner included, unconsciously uses much information which should be credited to other methods. I do not think the subject is appropriate for statistical analysis; it is certainly confused by partisan feeling.

P. Leicester: I entirely agree. One is always reading stories about people like Rockefeller and so on who made a success. I feel that we should collect a series of stories of people who have "put their shirt on oil," and who are now selling matches. The success is rather emphasized. When one mentions success ratio, I agree that not only is there this question of a lot of people who find oil by pure chance, but also, as I mentioned in the paper, in the small concession block type of work, one depends very largely on the information from the other people working the other small blocks around one. The difficulty is to get enough producing ground to make it a worthwhile operation and to get enough information to enable one, with the other fellows' results coming in, to make up one's mind whether one should stay in or get out. One can either regard a dry hole as an unfavourable indication or as a spot where not to look for the oil. I think one of the most difficult things in the business is the decision not only when to get in but when to get out. I think Ecuador is quite an interesting case. Every one of those six holes that we put down contained some oil which led us on to further effort. If the first few holes had been dry, we should probably have got out pretty cheaply.

J. H. G. Carlile: In regard to the question of success ratios in the past and present. Is not this largely a matter of the man who used to rely on a nose for oil, or a hunch, having a better chance of success in the past because oil was relatively easy to find, whereas now that oil is becoming more difficult to discover, it is essential to rely on scientific methods?

On the question of quality, I agree with Mr Ion that this is a matter of some importance to the refiner. Presumably there is, for example, a limit to the sulphur content of a crude that it is reasonable to work, just as there is with coal. In some parts of the world, sulphur contents of coal are so high that it is debatable whether the deposits should be worked for coal or for sulphur!

As regards the occurrence of sulphur in oil, is it possible over a large area to plot lines similar to isotherms, through points of equal sulphur content, giving a series of lines showing 2 per cent, 3 per cent, 4 per cent sulphur, and so on? This sort of thing has been done in surveys of coal fields in the U.K., where, by analysis of samples taken in different parts of the field, lines of equal volatile matter (isovols) have been plotted. I would be interested to know whether it would be possible to plot changes in oil quality in this way?

P. Leicester: I must say that I think that would be a very good idea. I do not know whether it has been done. The people who would know most about that, of course, would be those closely concerned with the Middle East, such as Mr Falcon for instance.

N. L. Falcon: Unfortunately one has to ask if one is going to draw it in a horizontal or a vertical plane.

P. T. Cox: I should like to add a note of caution to Mr Ion's plea for attaching greater importance to crude quality in planning exploration. The relationship between crude quality and geological environment and history is an important sphere of investigation which will doubtless lead to further valuable generalizations than are now possible. It would be a pity, however, if the results of such studies were used too soon to restrict the drilling of otherwise attractive prospects. Kuwait and Bahrein are examples of how premature generalization regarding crude quality retarded, to some extent, the discovery of Mesozoic crudes of good quality. Before these areas were tested, only very heavy crudes with high sulphur contents were known within the foreland area bordering the Arabian massif. Moreover, there was abundant and widespread evidence of oils of this type within this structural unit. On the other hand, all the better crudes then known in the region came from the strongly folded foothills zone of the Zagros Mountains in Persia or Iraq. A premature conclusion regarding the relation of crude quality and geological history did for a time prevent exploratory drilling in the less strongly folded areas west of the Persian Gulf.

P. Leicester: If I may revert to the discussion on the quality of oil, I think one would be interested to note the data in this paper illustrating the extreme contrast between the Klamono oil and the Wasian and Mogoi oil of Netherlands New Guinea—the Klamono is 18° API, asphaltic base, while that at Wasian, 138 miles away in the same Vogelkop (Bird's head, as we call it), is 49° API paraffinic base.

C. M. Pollock: One of the most interesting features of Mr Leicester's lecture is the speed with which the science of oil discovery has itself been evolving. Many people whose minds go back to the "twenties" remember a very different picture, and wish heartily that we had had the advantage of many of the methods that have since been developed and put into practice. In those days, it took us a very long time in a jungle country to establish a regional geological picture. Nowadays, the geologist can go out into the field for the first time, with a very much broader and better idea of the framework of the picture within which it is up to him to investigate the details with the greater variety of methods now available to him.

The meeting then closed with a unanimous vote of thanks to Mr Leicester.

A STUDY OF THE FLOW PROPERTIES OF RESIDUAL FUEL OILS USING ELECTRICAL CONDUCTIVITY METHODS*

By G. C. ACKROYD† and A. G. LOWE†

INTRODUCTION

THE flow properties of many residual fuel oils, particularly those of the waxy type of Middle East origin, show pronounced changes in rheological properties with age. Generally, these changes adversely affect the pumpability of such oils, and in extreme cases an oil which on preparation at a refinery could be easily handled, sets to a gel with a well-defined yield value. The importance of assessing the pumpability of residual fuel oils and of predicting their pumpability after a period of storage has been recognized in recent years, and a certain amount of work has been published on the subject.[1, 2]

For convenience in studying the structural changes taking place when an oil ages, it is desirable to have some means of accelerating the ageing process. In the past, such procedures have been developed and have generally included an initial heat treatment to eliminate the effect of the previous thermal history of the oil, followed by some form of shock chilling. On re-heating the shock-chilled oil to temperatures around 100° F and subsequently cooling, the oil is obtained in a highly viscous state—the so-called "low fluidity condition"—while on re-heating the shock-chilled oil to 140° to 160° F and then cooling, the oil is obtained in a state of low viscosity—the "high fluidity condition." At intermediate temperatures, oils of intermediate fluidity are obtained.

Marked differences between the crystalline states of the wax in oils in low and high fluidity conditions have been found;[1] in the low fluidity condition the wax is present as sub-microscopic crystals, while in the high fluidity condition it is present in the form of large aggregates. These differences in the crystalline form of the wax are sufficient in themselves to explain the large differences in rheological properties of oils in the two fluidity conditions, but it has been shown[1] that other constituents of the oil, particularly asphaltenes, also play some part in producing the large differences noted. Moreover, although artificially aged oils can be prepared having the same or even considerably greater viscosity than the same oil after prolonged natural storage, no evidence has so far been produced to show that the factors giving rise to the viscosity increases are the same in both cases. Microscopic examination of oils that have been in storage for a long time shows, in fact, that much of the wax is still present in the form of large aggregates of a type similar to those found in an oil in the high fluidity condition. From considerations of chemical potential it would be expected that the formation of large wax aggregates or crystals would be favoured by long storage, and that the sub-microscopic crystals of the low fluidity state are in an unstable condition.

In the present paper an account is given of the contribution of asphaltenes and resins to the electrical conductivity of a Middle East fuel oil. Then the results of similar measurements, made on naturally and artificially aged oils while undergoing shear, are given from which it is deduced that the structures present are of different types.

SEPARATION OF THE OIL INTO FRACTIONS BY SOLVENT EXTRACTION

The oil chosen for the experimental work was a straight-run residue supplied by the courtesy of the British Petroleum Company Ltd, and obtained by the refinery distillation at atmospheric pressure of a Middle East crude oil. Inspection data provided by the Company are given in Table I, together with pour point and other data determined at the Fuel Research Station.

The method used for the separation of the oil into fractions was devised to avoid, as far as possible, any treatment likely to produce a permanent change in the oil.

The asphaltenes were separated by the addition of 7½ parts of pentane to 1 part of oil by volume; the mixture was refluxed for 3 hr, allowed to stand overnight, and the supernatant liquid was then decanted from the asphaltenes, which were washed with cold pentane until the washings were colourless. The pentane washings were added to the decanted pentane solution, and the whole was refluxed for 3 hr, allowed to stand overnight, and decanted as before. The whole process was repeated a third time, and the decanted pentane solution centrifuged to remove the last traces of asphaltenes. The oil freed from asphaltenes, hereafter called the asphaltene-free fraction, was recovered from its pentane solution by distillation.

The resins were separated from the asphaltene-free fraction by the following procedure. A known amount of the asphaltene-free fraction was dissolved in benzene, and an amount of activated alumina added equal to three times the weight of the asphaltene-free fraction. The benzene was evaporated off, the mixture dried, and extracted with pentane. A yield

* MS received 24 January 1955.

† D.S.I.R. Fuel Research Station, East Greenwich.

of 85 per cent by weight of extract was obtained (calculated on the original oil). This extract is designated the asphaltene–resin-free fraction.

TABLE I

Properties of the Residual Oil Examined

Inspection data	
Volume on crude, %	50
Weight on crude, %	55·5
T.B.P. (cut point), ° C	285
Sp. gr. 60/60° F	0·931
Kinematic viscosity, at 100° F, cs	93
Ultimate analysis, wt %	
Ash	0·02
Carbon	84·85
Hydrogen	11·85
Nitrogen	0·2
Sulphur (total)	3·1
Difference	0
Moisture	Trace
Molecular weight *	397
Pour point, ° F:	
As received	55
After heat pretreatment at:	
80° F	40
90° F	55
100° F	65
110° F	65
120° F	40
130° F	0
140° F	−5
Asphaltenes (by IP 6/49), %	2·8
Wax (insoluble in CH_2Cl_2 at −25° F), %	10·3

* By elevation of the boiling point of benzene.

The wax was separated from this fraction by dissolving it in ten times its volume of methylene chloride, cooling to −25° F, and filtering at this temperature. The oil in the filtrate, when recovered from methylene chloride, is called the oil fraction.

MEASUREMENTS OF ELECTRICAL RESISTIVITY

Electrical resistivity measurements were made using a thermostatically controlled cell, the electrode system of which consisted of seven vertical brass plates, 5·1 cm square, held 0·2665 cm apart by glass spacers. The cell stood on a Perspex base in a 400-ml beaker which was filled with the oil under test. The electrode system was arranged so that the first, third, fifth, and seventh plates were connected to one side of a dry battery (3 to 240 V, depending on the oil) and the second, fourth, and sixth plates were connected to the other side of the battery. The effective area of the cell plates was 145·2 sq. cm. In order to reduce polarization effects to a minimum, measurements were made as soon as the current had become steady. Such readings were obtained about 3 minutes after the circuit had been closed and were accurate to within approx 2 per cent.

The resistivity of the original oil was determined, and was found to be constant over the range of potential difference of 3 to 240 V. Ohm's Law is therefore valid when applied to the fuel oil system, at least over this voltage range.

The viscosity of oils in the high and low fluidity conditions has been found to depend on the rate at which they are cooled from the re-heat temperature to the test temperature. As a relationship exists between viscosity and resistivity, it is important that the rate of cooling should be closely controlled. In the present work, all the data were obtained on oils that had been cooled to the test temperature at the same rate and are therefore directly comparable.

The oils used in the present work may be considered as disperse systems with oil as the continuous phase and asphaltenes, resins, and wax as the disperse phase. The change in resistivity of a disperse system with temperature may presumably be accounted for by the change in viscosity of the continuous phase and the change in the contribution made to the conductivity by the disperse phase. It can be

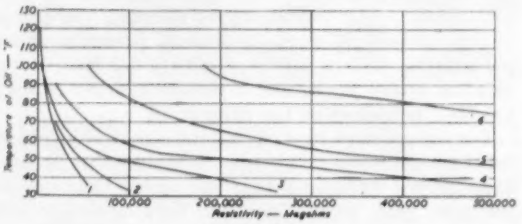

FIG 1

RELATIONSHIP BETWEEN RESISTIVITY AND TEMPERATURE OF OILS

1—Original oil maximum fluidity. 2—Asphaltene-free fraction maximum fluidity. 3—Original oil minimum fluidity. 4—Asphaltene-free fraction minimum fluidity. 5—Oil fraction. 6—Asphaltene–resin-free fraction.

expected that there will be a simple relationship between the resistivity and the viscosity of the continuous phase, but the effect of the disperse phase on the conductivity would not be expected, necessarily, to run parallel to its effect on the viscosity of the disperse system.

The resistivities of the original oil and the asphaltene-free fraction in the high and low fluidity conditions were determined at temperatures ranging from 90° to 32° F. In addition, the resistivities of the asphaltene–resin-free fraction and the oil fraction were determined at temperatures ranging from 100° to 40° F. Curves of the results are shown in Fig 1.

The resistivities of the original oil in the high or low fluidity condition are the same down to a temperature of 80° F, but, below this temperature, the resistivity of the oil in the low fluidity condition increases more rapidly than that of the oil in the high fluidity condition. The resistivity of the oil in the low fluidity condition at 32° F is 260,000 megohms compared with approx 65,000 megohms for the oil in the high fluidity condition.

The asphaltene-free fraction also has a much higher resistivity when in the low than in the high fluidity condition; in either case, its resistivity is higher than that of the corresponding original oil.

The resistivity of the asphaltene–resin-free fraction

is very high, being 180,000 megohms at 100° F and 400,000 megohms at 80° F. The resistivity of the oil fraction is lower, being 54,000 megohms at 100° F and 110,000 megohms at 80° F.

As already mentioned, a relationship exists between the resistivity of an oil and its viscosity, and this is shown in Fig 2, in which the resistivity of the unsheared oil at a particular temperature has been

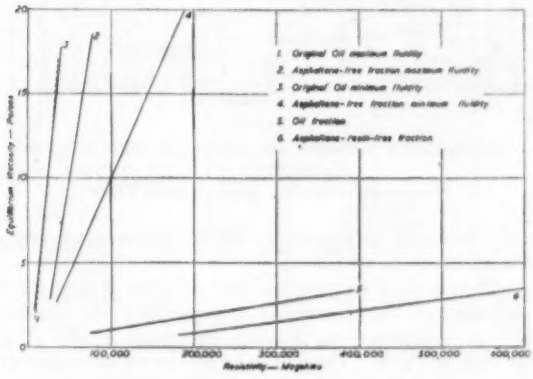

FIG 2

RELATIONSHIP BETWEEN RESISTIVITY AND EQUILIBRIUM VISCOSITY

Rate of shear 13·18 sec^{-1}.

plotted against the equilibrium viscosity (determined at a relatively high rate of shear, 13·18 sec^{-1}) at the same temperature, for the original oil and fractions derived from it. In all cases, a linear relationship is found, and although the slopes of the lines vary considerably, all pass close to the origin. It would appear that any change in resistivity which occurs when the temperature changes is due to the change in viscosity. At the present time, no reason can be advanced to account for this simple relationship between the electrical resistivity of an unsheared oil and its equilibrium viscosity.

It is clear, however, from the data presented that mixtures of asphaltenes and oil, and to a lesser extent, mixtures of resins and oil, have a much lower resistivity than the oil alone. The presence of wax in the oil increases the resistivity.

EXPERIMENTS USING A CO-AXIAL CYLINDER VISCOMETER

Ackroyd and Cawley,[1] working with the same oil and with the fractions derived from it, have shown that asphaltenes, resins, and wax under certain conditions, can contribute towards the formation of structures in the oil. On shearing, these structures are broken down; in the present paper the changes in the resistivity of the oil as shearing proceeds are examined.

For this work, a co-axial cylinder viscometer was used. It had a stainless steel stationary inner cylinder, 4·569 cm dia and 6·0 cm long, suspended by means of a torsion wire in a rotating stainless steel cup with an annular gap of 0·0883 cm. The outer cup was surrounded by a thermostatically controlled bath, and was rotated by a servo-controlled motor which kept a selected speed constant to within 0·5 per cent. A thin, circular, Perspex disk, made to cover the bottom of the cup, insulated it from the bottom of the cylinder. The torsion head from which the cylinder was suspended was also insulated from the main body of the viscometer by a Perspex collar. The inner cylinder and cup thus formed the electrodes of a conductivity cell. A potential difference was applied across the cell, and the current flowing in the circuit was measured by a galvanometer. The results obtained were accurate to within approx 5 per cent.

The oil, after suitable thermal pretreatment as previously described, was put into the viscometer at the re-heat temperature used in the pretreatment, and slowly cooled to the test temperature of 50° F. This temperature was selected since it was below the pour point of the oil in the minimum fluidity condition and, therefore, a certain amount of structure could be expected in the oil. Two hours after the temperature of the oil had reached 50° F, the viscometer was started and simultaneous measurements of the viscosity and the resistivity were obtained. It was found that reversal of the polarity of the electrodes had no effect on the results; moreover, the same results were obtained whether or not the current was allowed to flow continuously throughout an experiment or intermittently, showing that polarization effects were negligible.

Original Oil

The viscosities and resistivities of the original oil in the minimum and maximum fluidity conditions at

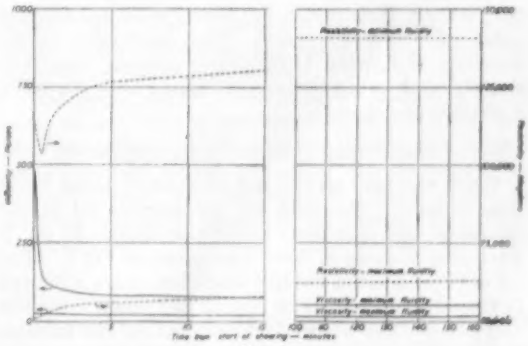
Resistivity — minimum fluidity
Resistivity — maximum fluidity
Viscosity — minimum fluidity
Viscosity — maximum fluidity
Time from start of shearing — minutes

FIG 3

RELATIONSHIP BETWEEN VISCOSITY AND RESISTIVITY OF ORIGINAL OIL

Temperature 50° F. Rate of shear 8 sec^{-1}.

50° F at a rate of shear of 8 sec^{-1} are shown, plotted against the time of shearing, in Fig 3.

The oil in the minimum fluidity condition shows a big fall in viscosity initially (from approx 490 poises

to approx 100 poises), followed by a more gradual fall towards the equilibrium value of approx 50 poises. The initial resistivity, before shearing, is approx 115,000 megohms. As shearing occurs, so the resistivity falls sharply to approx 105,000 megohms, and then rises rapidly to a value of approx 140,000 megohms. The viscosity of the oil in the maximum fluidity condition shows only a slight initial drop, and is then constant at approx 20 poises. The resistivity of this oil before shearing is approx 50,000 megohms, and gradually increases to approx 63,000 megohms as shearing continues.

Asphaltene–Resin-free Fraction

The effect of shearing the asphaltene–resin-free fraction, *i.e.* a fraction consisting of wax and oil only, is shown in Fig 4. The rate of shear was 8 sec^{-1}, and the temperature 50° F. The viscosity

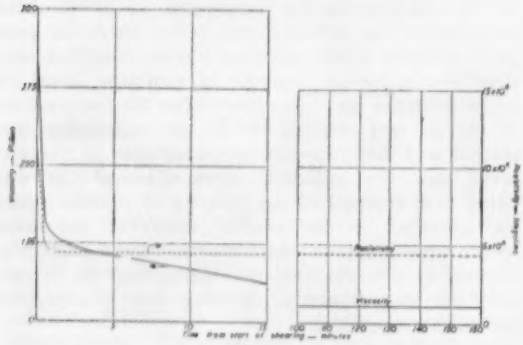

FIG 4

RELATIONSHIP BETWEEN VISCOSITY AND RESISTIVITY OF ASPHALTENE–RESIN-FREE FRACTION

Temperature 50° F. Rate of shear 8 sec^{-1}.

falls sharply from about 460 poises to an equilibrium value of about 25 poises. The resistivity, before shearing, is approx 11,000,000 megohms, and falls sharply on shearing to an equilibrium value of approx 4,400,000 megohms.

Effect of Lower Rates of Shear on the Original Oil

Work was also carried out at rates of shear lower than 8 sec^{-1}. The data for the original oil in the minimum and maximum fluidity conditions at 50° F for a rate of shear of 3 sec^{-1} are given in Fig 5. The oil in the minimum fluidity condition shows a big fall in viscosity initially (from approx 950 poises to approx 150 poises), followed by a more gradual fall towards the equilibrium value of approx 100 poises. The initial resistivity, before shearing, is approx 120,000 megohms. As shearing occurs, the resistivity falls sharply to approx 70,000 megohms, and then rises rapidly to a value of approx 140,000 megohms. The oil in the maximum fluidity condition shows only a slight initial drop in viscosity, the equilibrium value being approx 20 poises. The resistivity of this oil before shearing is approx 55,000 megohms and gradu-

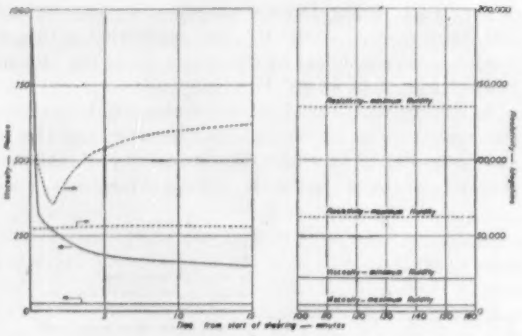

FIG 5

RELATIONSHIP BETWEEN VISCOSITY AND RESISTIVITY OF ORIGINAL OIL

Temperature 50° F. Rate of shear 3 sec^{-1}.

ally increases to approx 63,000 megohms as shearing continues.

The effect of varying the rate of shear from 1 sec^{-1} to 8 sec^{-1} on the viscosity and resistivity of the original oil in the minimum fluidity condition at 50° F is shown in Fig 6. The viscosity of the oil decreases as the rate of shear is increased. The equilibrium viscosities are approx 300, 100, and 50 poises for rates of shear of 1 sec^{-1}, 3 sec^{-1}, and 8 sec^{-1}, respectively. As the rate of shear increases, so the time taken for the viscosity to approach the equilibrium value decreases.

The initial resistivity, before shearing, of the oil in all three experiments is approx 115,000 megohms. The final resistivities, *i.e.* when the oil has been sheared to equilibrium, are approx 115,000 megohms at a rate of shear of 1 sec^{-1}, 135,000 megohms at a rate of shear of 3 sec^{-1}, and approx 140,000 megohms at a

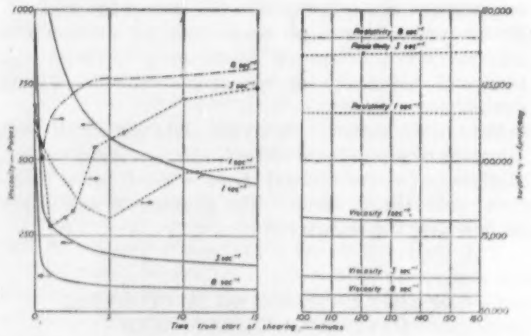

FIG 6

EFFECT OF RATE OF SHEAR ON VISCOSITY AND RESISTIVITY OF ORIGINAL OIL

Minimum fluidity condition. Temperature 50° F.

rate of shear of 8 sec^{-1}. At all rates of shear the resistivity falls initially as shearing begins, and then increases. The lower the rate of shear, the longer the time from the start of shearing before the resistivity commences to rise.

It has been shown (Fig 2) that a linear relationship

exists between viscosity and resistivity for a rate of shear of 13·18 sec^{-1}. However, from the data presented it is seen that as the rate of shear decreases, the

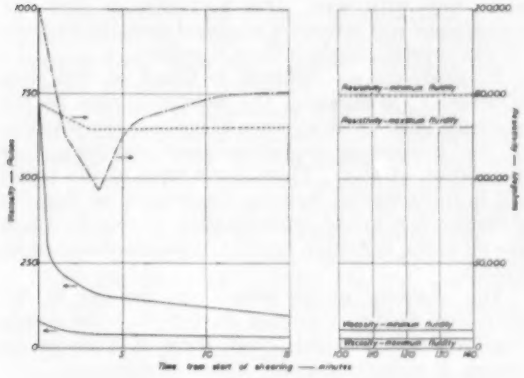

FIG 7

RELATIONSHIP BETWEEN VISCOSITY AND RESISTIVITY OF ASPHALTENE-FREE FRACTION

Temperature 50° F. Rate of shear 3 sec^{-1}.

viscosity increases, and the resistivity decreases. It is thus clear that the factors responsible for the changes in resistivity with the rate of shear are only indirectly related to changes in viscosity. A possible explanation of this behaviour is to assume that at least part of the anomalous viscous behaviour is due to the presence of asphaltene micelles, and that the larger the micelles the lower the resistivity. At low rates of shear these micelles are not broken up to the same extent as at higher rates of shear, giving the inverse relationship between viscosity and resistivity.

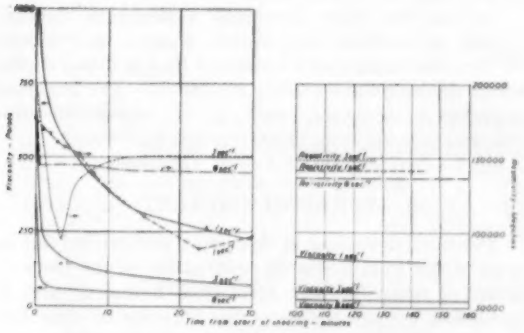

FIG 8

EFFECT OF RATE OF SHEAR ON VISCOSITY AND RESISTIVITY ASPHALTENE-FREE FRACTION

Minimum fluidity condition. Temperature 50° F.

Asphaltene-free Fraction

Data obtained with the asphaltene-free fraction at 50° F and a rate of shear of 3 sec^{-1} are shown in Fig 7. The viscosity of the oil in the minimum fluidity condition, as in the case of the original oil, shows a big initial fall from about 700 poises to about 100 poises, followed by a gradual fall to an equilibrium value of about 50 poises. The resistivity, before shearing, of this oil is about 175,000 megohms. As shearing occurs, the resistivity falls sharply to about 90,000 megohms followed by a rise to about 150,000 megohms. On shearing, the viscosity and resistivity of the oil in the maximum fluidity condition both show a slight initial fall levelling off to a steady value of 40 poises and 130,000 megohms respectively.

Effect of Rate of Shear on the Asphaltene-free Fraction

The effect of the rate of shear on the viscosity and resistivity of the asphaltene-free fraction, in the minimum fluidity condition at 50° F is shown in Fig 8. The viscosity of the oil decreases as the rate of shear increases. The equilibrium viscosities are 150, 50, and 25 poises for rates of shear of 1 sec^{-1},

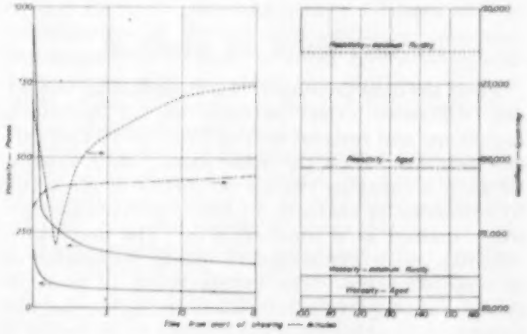

FIG 9

COMPARISON OF THE MINIMUM FLUIDITY CONDITION OF THE ORIGINAL OIL WITH THE AGED OIL

Temperature 50° F. Rate of shear 3 sec^{-1}.

3 sec^{-1}, and 8 sec^{-1}, respectively. As the rate of shear increases, so the time taken to approach the equilibrium value decreases.

The resistivity of the oil, before shearing, in all three experiments is 180,000–200,000 megohms, and the final resistivities are between 135,000 and 150,000 megohms. At all rates of shear the resistivity decreases initially with shearing; it then increases as shearing continues, except in the case of the experiment at 8 sec^{-1}.

Aged Oils

Measurements of viscosity and resistivity at 50° F and a rate of shear of 3 sec^{-1} were made on the original oil after it had been aged by storing at atmospheric temperature for about three years. The results are given in Fig 9, and a comparison is made with the oil in the minimum fluidity condition.

The viscosity of the aged oil decreases with shearing from approx 200 poises to an equilibrium value of approx 40 poises. The viscosity of the oil in the minimum fluidity condition decreases with shearing

from approx 950 poises to an equilibrium value of approx 100 poises.

The resistivity of the aged oil before shearing is 83,000 megohms. On shearing, this increases rapidly to approx 90,000 megohms, and then gradually rises to the equilibrium value of approx 97,000 megohms. The resistivity of the oil in the minimum fluidity condition decreases with shearing from approx 120,000 megohms to approx 70,000 megohms, and then increases rapidly to an equilibrium value of approx 140,000 megohms.

Similar tests, including observations on the oils in the minimum fluidity condition, were made on three other fuel oils, two from the Middle East and one from South America, which had aged by storing at atmospheric temperature. The viscosities and resistivities of these oils showed the same types of changes on shearing as observed for the oil used in the more comprehensive series of experiments.

DISCUSSION OF RESULTS

From the data presented, it is clear that an important difference exists between an oil containing asphaltene and resin on the one hand, and an asphaltene–resin-free oil on the other hand. Both types of oil show anomalous viscous properties as illustrated by a decrease in viscosity, to some equilibrium value, when sheared at a constant rate. The decrease in viscosity which occurs must be due to the breakdown of some structure. The interpretation of measurements of electrical resistivity made during the viscosity breakdown enables some conclusions to be drawn as to the type of structure present. In the asphaltene–resin-free system, the resistivity decreases to some equilibrium value as shearing continues, and it would appear that this decrease is merely due to the accompanying viscosity decrease. The changes in both viscosity and resistivity can be explained by assuming that the high initial viscosity is due to a structure built up through the crystallization of wax. As this is broken down through the shearing action, both viscosity and resistivity fall.

With the original oil in the minimum fluidity condition, the viscosity changes on shearing are much the same as for the oil free from asphaltenes and resins. The resistivity, however, falls initially and then rises; in some cases it rises to a value greater than the initial value. The initial fall can be interpreted as above, by assuming the breakdown of a wax structure, but the subsequent rise, taking place simultaneously with a decrease in viscosity, suggests that a conducting type of structure is being destroyed. It is envisaged that this conducting structure is made up of micelles of asphaltenes and resins; on shearing the micelles are broken up into smaller units, resulting in a lower viscosity and a higher resistivity.

However, it is important to note that the behaviour mentioned above only takes place in oils that contain moderate or large amounts of wax (6 to 10 per cent), and hence it appears that the conducting asphaltene–resin structure postulated must also be associated in some way with wax. One possibility is that the asphaltenes and resins are adsorbed over the surfaces of wax crystals, binding them together.

In aged oils no evidence is found of this dual structure. On shearing, the resistivity rises as the viscosity falls, which appears to indicate the presence of the conducting asphaltene–resin structure on a foundation of wax. There is no trace of the initial fall in resistivity as shearing commences, so that the structure due to the crystallization of wax, found in the oil in the minimum fluidity condition, seems to be absent.

The viscosity measurements on the oils in the maximum fluidity condition show them to be nearly true Newtonian liquids, and there is little or no change in resistivity with the time of shearing.

SUMMARY AND CONCLUSIONS

The viscosity and electrical resistivity of a residual fuel oil of Middle East origin have been determined in the low and high fluidity conditions. In addition, similar measurements were made on the same oil after it had been stored for a few years.

The constituents of the oil primarily responsible for electrical conduction are the asphaltenes and resins.

In an oil in the minimum fluidity condition there is evidence of two types of structure. One appears to be due to an interlocking network of wax crystals, and the other to the presence of asphaltene–resin micelles in some form of association with wax. Oils in the maximum fluidity condition show little evidence of any structure of this kind.

In oils that have developed a structure through storage at ambient temperature, there is no evidence of the interlocking wax structure that is found in the oil in the minimum fluidity condition. The evidence suggests a structure made up of asphaltene–resin micelles in some form of association with wax.

ACKNOWLEDGMENT

The work described in this paper was carried out as part of the Fuel Research programme of the Department of Scientific and Industrial Research, and is published by permission of the Director of Fuel Research. The illustrations are Crown copyright, and are reproduced by permission of the Controller, H.M. Stationery Office.

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[1] Ackroyd, G. C., and Cawley, C. M. *J. Inst. Petrol.*, 1953, **39**, 82.

[2] Gill, F., and Russell, R. J. *Industr. Engng Chem.*, 1954, **46**, 1264.

HYDROCARBON RESEARCH GROUP REPORT FOR 1954

THE eight contributory member organizations of the Group remain the same, namely British Petroleum Company Ltd., Esso Development Company Ltd., Imperial Chemical Industries Ltd., Ministry of Supply, Monsanto Chemicals Ltd., National Coal Board, Shell Petroleum Company Ltd., and Trinidad Leaseholds Ltd. The income during the year was £9000, an increase of £1000 over normal because of the agreement by the Ministry of Supply to fall into line with other members by paying subscription in advance. The expenditure during the year amounted to £7485 13*s.* 9*d.* of which £7247 17*s.* 10*d.* was made up of direct grants and honoraria to universities. This leaves a credit balance of £1932 4*s.* 6*d.* to be carried forward to next year.

The Spectroscopic Panel supported research (£2250) at Cambridge, Oxford, and King's College, London, and this has again been most productive of results. As many as thirty papers have been published, and a further twenty are in course of publication. Most striking, perhaps, has been the development of new instruments and techniques, both with infra-red and ultra-violet. The broad programme of fundamental work has also been maintained, with industrial applications already evident from some results.

A very well-attended Conference on Molecular Spectroscopy was organized by the Spectroscopic Panel in October. Of the twenty papers, covering almost the whole field of molecular spectrometry, six dealt with work sponsored by the Group and five came from overseas.

The Mass Spectrometry Panel continued support (£1425) at Birmingham, Liverpool, and King's College, London. New techniques have been developed and good progress made in the measurement of ionization potentials and energy levels. The techniques are being broadly applied to include study of the formation of intermediates in hydrocarbon oxidations, processes initiated by atomic oxygen, homogeneous radical reactions, and reactions on filaments.

The Hydrocarbon Chemistry Panel supported work (£2690) at Bedford College, Birmingham University, Queen Mary College, and Oxford. Assistance to Bedford College will now cease, and a programme of fundamental research in physical chemistry will be initiated at Bristol under Professor Everett. Interesting new synthetic routes have been disclosed and an understanding of chromic acid oxidations obtained. Programmes are in hand to study hydrocarbon and ketone isomerization, whilst the synthesis of pure hydrocarbons is maintained for the definition of the courses of several reactions.

The Group thus continues to cover a wide field of physics and chemistry applied to hydrocarbons. Many of the techniques are of very wide application and the Group can justifiably claim that its achievement in promoting new and important uses of spectrometric methods has been extremely successful. The policy of reasonably continuous support of active centres of work appears sound and will be continued and extended in the coming year.

J. W. BARRETT
Chairman

February 1955

ERRATUM

EMULSIFICATION TEST FOR MARINE ENGINE OILS

Page 371, Volume 40, December 1954 and page 182, Volume 41, May 1955

Section 3(a) Graduated Cylinder—of 100-ml capacity, graduated in 1- and 10-ml divisions, approx 254 mm in height and 30 mm, + 1 mm,—zero in internal diameter. The bottom should be flat and at right angles to the walls.

THE INSTITUTE OF PETROLEUM

ANNUAL REPORT

For the Year Ending 31 December 1954

GENERAL

The Institute was honoured by the presence of His Royal Highness the Duke of Gloucester at the Annual Dinner in February.

1954 has been a year of steady progress. The new size periodicals have been well received by members, and several important publications have made their appearance during the year.

General Meetings

Twelve General Meetings were held and were well attended. The average attendance was ninety-five, approximately 55 per cent of whom were visitors.

Cadman Medal

The 4th Cadman Memorial Lecture was delivered at The Royal Institution before a large audience by Mr C. A. P. Southwell, C.B.E., M.C., B.Sc., managing director of the Kuwait Oil Co. Ltd., and a Past-President of the Institute. The title of his lecture was "Winning Petroleum." The President presented him with the Cadman Medal at the conclusion of his address.

Annual Dinner

The Annual Dinner was held at Grosvenor House on 24 February, when the Institute was honoured by the presence of His Royal Highness the Duke of Gloucester, who was the chief speaker. The attendance was the largest in the history of the Institute, over 1100 members and guests being present.

Summer Meeting

A very successful Summer Meeting was held at the Grand Hotel, Llandudno, in May. 150 members and their wives attended and, except in those years when a World Petroleum Congress is being held, it is intended to make the Summer Meeting a regular annual function of the Institute.

The next Summer Meeting will take place at Torquay in 1956.

At the Llandudno meeting a programme of nine papers was presented under the theme "The Rôle of Petroleum in Modern Transport," and these meetings were well attended. A most enjoyable social programme was arranged, including tours to well-known places of historical interest.

Economics and Operations Group

During the year this new group, under the chairmanship of Mr O. F. Thompson, catering for a wide section of the Institute's membership primarily interested in economics, distribution, and transport, continued its steady growth, and membership is now over 100. Five meetings were held, and attendances were satisfactorily maintained.

Studentship

Mr B. Bennett was awarded the Institute's Annual Prize at the Imperial College of Science and Technology, and Mr H. J. V. Charlton was awarded the Institute's Scholarship at Birmingham University.

Aviation Products Data Committee

It is understood that the Royal Aeronautical Society will publish in the near future the additional data sheets prepared by the Committee over a year ago. In view of the lapse of time, it will be necessary to bring certain of these data sheets up to date.

Awards

The first award of the Institute of Petroleum Eastlake Medal for long and meritorious service to the Institute was made in June to Mr G. H. Coxon. In a ceremony following the Annual General Meeting the Honorary Fellowship of the Institute was conferred upon Mr T. Dewhurst.

Benevolent Fund

Three applications for assistance have been considered and grants made during the year.

Branches Committee

The year 1954 was another successful year for the Branches and attendances at Branch meetings continued to rise.

Engineering Committee

Towards the end of 1954 the Marketing Safety Code appeared in print. The revision of the Re-

fining Code has taken longer than anticipated, but at the end of the year little remained to be done except final editing prior to printing. It is hoped to publish this Code early in 1955.

The Production Code was studied in draft form, and at the end of the year a final re-draft taking into account recommended alterations was close to completion. This Code will be printed and published after the Refinery Code has been issued.

The Electrical Sub-Committee has given consideration to and has produced in draft form the amendments necessary to cover the inclusion in the Electrical Safety Code of rules for "Remotely Dangerous Areas." Any other necessary modifications will be made in the Electrical Code when this is reprinted to bring the recommendations in all four Codes into uniformity.

The Electrical Sub-Committee has also worked on the problem of the generation of static electricity due to flow through pipelines.

The first meeting of the Safety Sub-Committee took place in January 1954, and monthly meetings were held until July, by which time personal contacts were well established. Some useful discussions on safety matters were held.

Various requests for information and advice from public and private organizations have been dealt with by the Engineering Committee.

Education Committee

The Committee has given guidance to the Institute of Weights and Measures Administration on the organization for their Inspectors of a course of study and proposed examination in connexion with petroleum inspection. It has also advised the County Inspector of Schools, Essex, regarding the installation of equipment for the Oil Technology Laboratory at the new Technical College, Thurrock.

Following the chairman's discussion with the City and Guilds of London Institute on the subject of their proposed syllabus and examination for plant operators in the chemical industry, it was evident that the syllabus did not meet the requirements of the petroleum industry. The Guild were so informed.

The Institute accepted the invitation to a conference at the University of Trieste in July when post-school and post-university education for the training in various European countries of technical staff for the petroleum industry was discussed. Representatives of seven countries attended.

Finance

The Institute had a satisfactory year financially and the full accounts are appended to this report.

House

The Staff at Manson House did not alter during the year.

The recording system at meetings has now been very greatly improved by the purchase of a new tape recorder of the most modern pattern, and the facilities now available have enabled many important papers read before the Branches to be included in the *IP Review*.

Council desires to record again the debt which it owes to the many members of the Institute who have assisted in the work of the various committees, sub-committees, and panels, and to the member companies who have provided facilities for co-operative laboratory work.

In particular, the permanent staff of the Institute have contributed in no small measure to the successful year which the Institute had in 1954, and Council is glad to record its appreciation of the services rendered by all concerned.

Public Relations

It has been decided to issue a new and up-to-date IP Brochure, which it is hoped to publish during 1955.

Publications

Professor F. H. Garner relinquished the Honorary Editorship of the Institute at the Annual General Meeting. The Institute owes a very real debt of gratitude to Professor Garner for his guidance during the difficult post-war years which has done so much to bring the publications of the Institute to their present high standard.

Professor Garner has been succeeded by Dr E. B. Evans, and Mr D. L. Samuel has succeeded Dr Evans as Honorary Associate Editor.

The year 1954 was the start of a new era in the history of the IP periodicals, for both the *Journal* and the *Review* appeared in their new and enlarged form. A study of these two publications shows that the advantages claimed for the quarto page have been more than justified, particularly in the case of the *IP Review*.

During the year the fortieth volume of the *Journal* was published in regular monthly parts. As usual, it contained the papers read at the Ordinary General Meetings and a number of contributions on various aspects of petroleum technology. The Abstracts of current literature continued to be a valuable feature of the *Journal*.

There is no doubt that the *IP Review* is a most popular journal with members and also with readers who subscribe to it. The eighth volume was issued during 1954, and due to its new size was even more attractive than the preceding volumes.

Other Publications

The year 1954 was particularly active in regard to book publications. The first to make its appearance was the full report of the 1953 Summer Meeting under the title of "Post-war Expansion of the U.K. Petroleum Industry."

Three other publications were issued in 1954. These are: "Significance of Properties of Petroleum Products"; "Modern Petroleum Technology" (2nd edition); and the "Marketing Code."

At the end of the year considerable progress has been made towards the compilation of the following: "Standard Methods for Testing Petroleum and its Products" (14th edition) and its new companion volume, "IP Engine Tests for Rating Fuels"; "The Rôle of Petroleum in Modern Transport" (1954 Summer Meeting); "Application of Mass Spectrometry"; and "A Glossary of Petroleum Terms" (2nd edition).

Conferences

Another very successful conference was held in London under the auspices of the Spectroscopic Panel of the Hydrocarbon Research Group on "Molecular Spectroscopy."

Considerable discussion followed the presentation of the various papers, and the full report will be published by the Institute in book form during 1955.

Library

The re-classification of the library has proceeded steadily, and the Library Sub-Committee are to be congratulated on the progress made during the year. The increased use made of the library has been most noticeable, and it is hoped the library catalogue will be issued during 1955.

Research

The Hydrocarbon Research Group, through its panels, continues to sponsor an increasing amount of work, including the chemistry of hydrocarbons, mass spectroscopy, and spectroscopy, at universities and colleges.

The Research Group No. 2 has again co-operated with the Medical Research Council in investigations of the biological activity of petroleum fractions.

Standardization

The 14th edition of "Standard Methods" and the first edition of "IP Engine Test Methods for Rating Fuels" were issued in January 1955. Work is proceeding on the 15th edition of "Standard Methods," which should be published early in 1956.

Considerable progress has been made in regard to co-operation with other standardizing bodies. During the year representatives of the British Standards Institution and of the Bureau de Normalisation du Petrole (France) were appointed to Standardization Committee, and two representatives of the Institute to ASTM Committee D-4 on Road and Paving Materials.

Since 1952 the number of IP standard methods technically equivalent to the corresponding ASTM methods has increased from eight to sixteen, with a further seven methods technically equivalent so far as those products within the scope of the IP method are concerned.

Discussions are in progress with the BSI with a view to the adoption of certain IP methods as British National Standards, so that, where desirable, they can be put forward for adoption by the International Organization for Standardization.

World Petroleum Congress—British National Committee

Through the year the British National Committee of the World Petroleum Congress has been actively engaged in organizing the presentation of papers by British representatives at the Fourth World Petroleum Congress to be held in Rome in June 1955. Representatives from the U.K. on the Council of the Congress are the President and Mr H. S. Gibson, with one other yet to be nominated to replace Mr T. Dewhurst who has recently felt obliged to give up this work after having served on the Council of the Congress continuously since its inception in 1933.

MEMBERSHIP

Details of membership as at 31 December 1954:

	Total Dec. 31 1953	Changes during 1954						Total Dec. 31 1954
		New	Transferred to	Resigned	Deceased	Transferred from	+ or −	
Honorary Members	3	—	—	—	1	—	− 1	2
Honorary Fellows	5	—	—	—	—	—	—	5
Members	608	30	6	28	3	5	—	608
Fellows	608	46	13	15	7	3	+ 34	642
Associate Members	845	64	1	48	2	4	+ 11	856
Associate Fellows	921	141	11	32	3	7	+110	1031
Students	113	14	—	33	—	12	− 31	82
Totals	3103	295	31	156	16	31	+123	3226
Member Companies	183	4	—	7	—	—	− 3	180

Once again the membership has shown a gratifying increase, and the Associate Fellowship has now risen to over 1000.

DEATHS

The Council wish to express their sincere condolences to the families and friends of the following members who died during the year :

C. H. Barton (F)
J. W. Burford (M)
Sir J. T. Cargill Bt. (Hon.M)
J. F. C. Coppens (AF)
S. R. Dunn (AF)
R. J. Gaul (AF)
W. H. Henderson (F)
G. J. Holbeche (AM)
H. G. Koefoed (F)
F. J. Nellensteyn (F)
M. A. Ockenden (F)
R. R. Rakestraw (F)
F. G. Rappoport (F)
G. van Wageningen (M)
A. Watson (AM)
F. A. Willcox (M)

Sir John Cargill, an Hon. Member, was one of those who took a leading part in the formation of the Institute as the Institution of Petroleum Technologists. He signed the original Articles of Association on 8 April 1914, and was included in these Articles as a Founder Member. He was elected a Member of the First Council of the Institution and remained on the Council until the end of the 1933–34 Session. During this period he served as a Vice-President from 1923 to 1933.

By Order of the Council,
C. CHILVERS,
Honorary Secretary

THE INSTITUTE

(A Company limited by Guarantee

BALANCE SHEET AS

1953 £		£ s. d.	£ s. d.
	Capital of the Institute under Bye-Laws 36, 44, and 45 :		
	Life Membership Fund—		
1,009	As at 31 December 1953	1,008 17 9	
	Entrance and Transfer Fees—	£ s. d.	
	As at 31 December 1953	6,963 4 9	
	Add Receipts during 1954—		
	Entrance Fees	364 7 0	
	Transfer Fees	11 11 0	
6,963		7,339 2 9	
	Profit on Sale of Investments—		
258	As at 31 December 1953	257 19 4	
	Add Profit on Sale of £664 6*s.* 6*d.* 3% London County Consolidated Stock 1920	20 5 0	
		278 4 4	
	Donations—		
326	As at 31 December 1953	326 5 0	
8,556			8,952 9 10
5	**T. C. J. Burgess Prize Fund**		5 0 0
1,702	**General Reserve (previously War Contingencies Reserve)**		1,702 0 11
	Revenue Account :—		
	As at 31 December 1953	15,833 14 4	
15,834	*Add* Surplus for year	5,833 1 0	21,666 15 4
	Subscriptions Received in Advance :—		
	Members' Subscriptions for 1955	1,755 12 0	
	Members' Subscriptions for 1956	17 17 0	
	Members' Subscriptions for 1957	11 0	
	Member Companies' Subscriptions for 1955	460 0 0	
	Journal Subscriptions for 1955	1,284 5 9	
	Journal Subscriptions for 1956	31 0 7	
	Journal Subscriptions for 1957	15 11 0	
4,453			3,564 17 4
	Current Liabilities and Provisions :—		
	Provision for Pension	350 0 0	
	Sundry Creditors and Accrued Charges	9,384 2 10	
	World Petroleum Congress	312 2 3	
	Entertainment Account—	£ s. d.	
	As at 31 December 1953	703 17 5	
	Add Excess of Receipts over Expenditure during year to date	325 4 7	
		1,029 2 0	
6,433			11,075 7 1
	Sum Set Aside for Grants to Branches and Students' Section—unallocated :—		
	Balance as at 31 December 1953	94 3 0	
	Add Amount set aside during year	600 0 0	
		694 3 0	
94	*Less* Grants made during year	605 0 0	
			89 3 0
£37,077			£47,055 13 6

AUDITORS' REPORT TO THE MEMBERS

We have examined the above Balance Sheet and annexed Revenue Account and report that we have obtained all the
In our opinion proper books of account have been kept by the Institute, so far as appears from our examination of those
best of our information and according to the explanations given to us, the accounts give the information required by the
affairs at 31 December 1954, and the Revenue Account gives a true and fair view of the revenue for the year ended on that

88 Leadenhall Street,
London, E.C. 3.

1 *March* 1955.

OF PETROLEUM

and not having a Share Capital)

AT 31 DECEMBER 1954

1953 £		£ s. d.	£ s. d.
	Investments :—		
	On account of Capital, at cost—		
	£525 0 0 3% Savings Bonds, 1955/65	525 0 0	
	867 8 6 2½% Bristol Corporation Redeemable Stock, 1955/65	845 17 7	
	150 0 0 3% Smethwick Corporation Redeemable Stock, 1956/58	151 4 9	
	150 0 0 3% Luton Corporation Redeemable Stock, 1958	151 6 7	
	806 8 3 3% Manchester Corporation Redeemable Consolidated Stock, 1958	845 17 7	
	600 0 0 3% Bristol Corporation Redeemable Stock, 1958/63	597 7 3	
	517 4 0 3% Funding Stock 1966/68	501 15 6	
	400 0 0 3% Metropolitan Water Board " A " Stock, 1963	346 10 7	
	193 0 0 3% British Gas Guaranteed Stock, 1990/95	154 8 6	
	156 9 8 3% British Transport Guaranteed Stock, 1978/88	105 4 9	
	461 0 0 2½% Funding Loan, 1956/61	461 15 6	
	500 0 0 2½% Defence Bonds	500 0 0	
5,166			5,186 8 7
	(Market Value at 31 December 1954, £5,174.)		
3,390	Cash on Deposit with Post Office Savings Bank		3,766 1 3
8,556			8,952 9 10
	On account of Revenue, at cost—		
	£3,092 4 8 3% Funding Stock, 1966/68	3,000 0 0	
	2,942 2 9 3% Savings Bonds, 1955/65	2,975 0 0	
	2,000 0 0 3% Savings Bonds, 1960/70	2,000 0 0	
	1,000 0 0 3½% Defence Bonds	1,000 0 0	
4,975			8,975 0 0
	(Market Value at 31 December 1954, £8,893.)		
	Office and Library Furniture :—		
	Valuation, being Net Amount standing in the Company's Books at 1 July 1948 *less* Sales	221 10 8	
	At Cost	2,486 9 7	
		2,708 0 3	
	Less Aggregate Depreciation	945 1 6	
1,568			1,762 18 9
15,099			19,690 8 7
	Current Assets :—		
5,877	Stock of Publications in hand as certified by the General Secretary	3,876 7 0	
6,777	Sundry Debtors and payments in advance, including Income Tax recoverable	7,027 10 5	
—	*Subscriptions in arrear (not valued)*	— — —	
	Cash on Deposit with Post Office Savings Bank— £ s. d.		
455	General Account 262 16 7		
390	World Petroleum Congress 312 2 3		
		574 18 10	
	Cash at Bank—		
3,000	Deposit Account 10,000 0 0		
4,090	Current Account 4,257 6 8		
789	Entertainment Account 1,029 2 0		
		15,286 8 8	
600	Cash in Hand	600 0 0	
			27,365 4 11
£37,077			£47,055 13 6

OF THE INSTITUTE OF PETROLEUM

information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit. books. The Balance Sheet and Revenue Account are in agreement with the books of account. In our opinion, and to the Companies Act, 1948, in the manner required, and the Balance Sheet gives a true and fair view of the state of the Institute's date.

SMITH & WILLIAMSON,
Chartered Accountants.
Auditors.

THE INSTITUTE

(A Company limited by Guarantee

REVENUE ACCOUNT FOR THE

1953 £	£		£ s. d.	£ s. d.
		To **Administrative Expenses :**		
9,419		Staff Salaries and National Insurance	10,365 3 4	
862		Staff Pension Scheme Contributions	1,192 15 3	
10,281			11,557 18 7	
4,743		*Less* Applicable to Publications	5,546 16 9	
	5,538			6,011 1 10
817		Printing and Stationery	1,241 1 3	
687		General Postages	792 17 10	
283		Telephones, Cables, and Travelling Expenses	287 8 4	
1,787			2,321 7 5	
596		*Less* Applicable to Publications—one-third	773 15 10	
	1,191			1,547 11 7
	74	Audit Fee	73 10 0	
	36	Legal Fees	— — —	
	188	General Expenses	196 0 7	
	33	Insurance	41 0 3	
				310 10 10
	7,060			7,869 4 3
		„ **Establishment Expenses :**		
2,500		Rent	2,500 0 0	
458		Cleaning, Lighting, and Heating	533 16 9	
45		Repairs and Maintenance	104 4 7	
3,003			3,138 1 4	
751		*Less* Applicable to Publications—one-fourth	784 10 4	
	2,252			2,353 11 0
		„ **Meetings :**		
	481	Hire of Hall, Pre-prints, Reporting, etc.		478 15 8
	500	„ **Sum Set Aside for Grants to Branches and Students' Section**		600 0 0
		„ **Sundries :**		
		Library Expenses	204 7 10	
		Subscriptions to Societies	78 10 11	
		Scholarship Awards	50 0 0	
		Depreciation of Furniture (10%)	183 9 5	
	433			516 8 2
		„ **Publications Revenue Account :**		
	3,117	Deficit for year		2,133 14 1
	5,378	„ **Balance, being Surplus Revenue for year**		5,833 1 0
	£19,221			£19,784 14 2

OF PETROLEUM

and not having a Share Capital)

YEAR ENDED 31 DECEMBER 1954

1953 £		£	*s.*	*d.*
9,895	By **Members' Subscriptions received for 1954**	10,418	11	0
155	„ **Members' Subscriptions in Arrear, received during year**	193	4	0
8,681	„ **Member-Company Subscriptions received for 1954**	8,600	4	6
10	„ **Member-Company Subscriptions in Arrear, received during year**	15	15	0
20	„ **Special Subscription**	20	0	0
460	„ **Interest and Dividends received (Gross)**	536	19	8
£19,221		£19,784	14	2

PUBLICATIONS

Revenue Account for the Year ended 31 December 1954

	£	s.	d.		£	s.	d.
To Stock in Hand at 1 January 1954	5,876	18	6	By Advertising	13,429	14	3
„ Dispatch Expenses	849	0	11	„ Journal	3,140	8	11
„ Journal	7,659	11	9	„ IP Review	372	10	10
„ IP Review	4,618	3	9	„ Standard Methods	1,925	6	3
„ Abstracts	404	1	6	„ Reviews of Petroleum Technology	482	4	0
„ Modern Petroleum Technology	2,069	19	10	„ Modern Petroleum Technology	45	5	0
„ Tables for Measurement of Oil	18	5	0	„ Electrical Code	166	13	0
„ Significance of Properties of Petroleum Products	237	5	3	„ Petroleum Measurement Manual	344	10	0
„ Post-war Expansion of U.K. Petroleum Industry	653	8	9	„ Tables for Measurement of Oil (British Edition)	1,327	14	0
„ Other Publications	74	12	7	„ Tables for Measurement of Oil (Metric Edition)	1,672	5	0
„ Publicity	149	12	11	„ Significance of Properties of Petroleum Products	150	7	6
„ Salaries, National Insurance, and Pension Scheme Contributions	5,546	16	9	„ Post-war Expansion of U.K. Petroleum Industry	406	10	0
„ Proportion of Administrative Expenses	773	15	10	„ Other Publications	246	8	10
„ Proportion of Establishment Expenses	784	10	4	„ Stock in Hand at 31 December 1954	3,876	7	0
„ Bad Debts written off	3	15	0		27,586	4	7
				„ Balance, being Deficit for year carried to Revenue Account	2,133	14	1
	£29,719	18	8		£29,719	18	8

HYDROCARBON RESEARCH GROUP

Revenue Account for the Year ended 30 September 1954

	£	s.	d.	£	s.	d.
To **Grants :**						
King's College	875	0	0			
University of Oxford	1,000	0	0			
University of Oxford (Professor Robinson)	200	0	0			
University of Birmingham	450	0	0			
Bedford College	1,150	0	0			
Queen Mary College	1,580	0	0			
University of Liverpool	650	0	0			
University of Cambridge	800	0	0			
	6,705	0	0			
Less Refunded Bedford College	339	12	2			
				6,365	7	10
,, **Honoraria**				682	10	0
,, **General Expenses**				37	2	1
,, **Wages**				350	0	0
,, **Contribution to Institute of Petroleum re cost of publication of Mass Spectrometry**				47	3	3
,, **Balance, being Surplus for Year**				517	16	10
				£8,000	0	0

	£	s.	d.
By **Voluntary Contributions from Members of the Group**	8,000	0	0
	£8,000	0	0

For convenience in administration the Accounts of the Group are closed as at 30 September each year

Statement of Funds at 30 September 1954

	£	s.	d.	£	s.	d.
Sundry Creditor—The Institute of Petroleum				262	10	0
Revenue Account :						
As at 30 September 1953	1,155	8	3			
Add Surplus for year	517	16	10			
				1,673	5	1
				£1,935	15	1

	£	s.	d.
Sundry Debtor	3	10	7
Cash at Bank on Current Account	1,932	4	6
	£1,935	15	1

We have examined the above Revenue Account and Statement of Funds with the books and vouchers of the Group and find them to be in accordance therewith.

88 Leadenhall Street,
London, E.C. 3.
1 *March* 1955.

Smith & Williamson.
Chartered Accountants.
Auditors.

CARCINOGENICITY RESEARCH FUND

Statement of Funds as at 31 December 1954

	£ s. d.	£ s. d.		£ s. d.
Balance of Sum Received from the Petroleum Board (during 1947)	1,450 0 0		**Cash at Bank on Current Account**	454 10 1
Less Grant made to Birmingham University	1,000 0 0			
		450 0 0		
Interest on Bank Deposit Account, as at 1 January 1954	2 15 7			
Add Interest received during year	1 14 6			
		4 10 1		
		£454 10 1		£454 10 1

We have examined the above Statement of Funds with the books and vouchers of the Fund and find it to be in accordance therewith.

88 Leadenhall Street,
London, E.C. 3.
1 *March* 1955.

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Auditors.

CADMAN MEMORIAL FUND

Income and Expenditure Account for the Year ended 31 December 1954

	£ s. d.	£ s. d.		£ s. d.
To **Cost of Cadman Medals and Expenses of Dinner**		199 19 5	By **Balance at 31 December 1953**	3,416 7 5
„ **Balance at 31 December 1954 :**			„ **Interest received gross**	89 1 2
Sundry Debtor	2 2 0			
Cash at Bank on Deposit Account	500 0 0			
Cash at Bank on Current Account	73 7 2			
£2,730 3% Savings Bonds 1965/75	2,730 0 0			
(Market Value at 31 December 1954—£2,566)		3,305 9 2		
		£3,505 8 7		£3,505 8 7

We have examined the above Income and Expenditure Account with the books and vouchers of the Fund, and find it to be in accordance therewith.

88 Leadenhall Street,
London, E.C. 3.
1 *March* 1955.

Smith & Williamson.
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Auditors.

BENEVOLENT FUND

Income and Expenditure Account for the Year ended 31 December 1954

1953 £		£ s. d.	£ s. d.	*1953* £		£ s. d.
65	To **Grants paid**		205 0 0	*3,092*	By **Balance at 31 December 1953**	3,198 7 9
	„ **Balance at 31 December 1954 :**			*115*	„ **Subscriptions and Donations received during year**	205 16 4
	Represented by—			*56*	„ **Interest received (gross)**	69 12 10
	Sundry Debtor	50 0 0				
	Cash at Bank on Current Account	268 16 11				
	Cash at Bank on Deposit Account	900 0 0				
	£200 3% Defence Bonds	200 0 0				
	£1,550 2½% Defence Bonds	1,550 0 0				
	£300 3½% Defence Bonds	300 0 0				
3,198			3,26 16 11			
	(Market Value of Investments at 31 December 1954, £2,050)					
£3,263			£3,473 16 11	*£3,263*		£3,473 16 11

We have examined the above Income and Expenditure Account with the books and vouchers of the Fund and find it to be in accordance therewith.

88 Leadenhall Street,
London, E.C. 3.
1 *March* 1955.

Smith & Williamson.
Chartered Accountants.
Auditors.

THE INSTITUTE OF PETROLEUM

FORTY-SECOND ANNUAL GENERAL MEETING

THE Forty-second Annual General Meeting of The Institute of Petroleum was held at 26 Portland Place, London, W.1, on 21 April 1955. Lt.-Col. S. J. M. Auld, O.B.E., M.C., D.S.O., presided.

The notice convening the meeting was read by the General Secretary and the minutes of the Forty-first Annual General Meeting held on 21 April 1954 were read, confirmed, and signed.

ELECTION OF OFFICERS FOR THE SESSION 1955–56

President

On the motion of T. Dewhurst, seconded by C. Chilvers, the nomination by the Council of Lt.-Col. S. J. M. Auld as President for the Session 1955–56 was approved with acclamation.

In proposing the election of Lt.-Col. Auld as President, Mr Dewhurst referred to the fact that this was the first occasion in the history of the Institute that one person had been nominated for the Presidency for the fourth time. This unique record, he said, afforded the highest tribute to the President.

Vice-Presidents

Lt.-Col. Auld proposed, W. S. Ault seconded, and it was unanimously agreed that the following, nominated by the Council, be elected to serve as vice-presidents for a term of three years :

Dr E. B. Evans
A. C. Hartley, C.B.E.
E. J. Sturgess

Council

It was announced that fifteen nominations had been received to fill twelve vacancies on the Council and that, as the result of the ballot, the following had been elected as Members of Council for a period of three years :

V. Biske
E. J. Dunstan
F. L. Garton
A. J. Goodfellow
N. W. Grey
H. Hyams
E. C. Masterson
T. W. Mathias, O.B.E.
J. S. Parker
R. B. Southall, C.B.E.
A. R. Stark
W. H. Thomas

Honorary Treasurer

A proposal by H. Hyams, seconded by J. S. Parker, that G. H. Coxon be re-elected as Honorary Treasurer was carried unanimously.

Honorary Secretary

W. H. Davies proposed and N. Fraser seconded that C. Chilvers be re-elected as Honorary Secretary, a motion which was unanimously approved.

Ex-officio Members of Council

The following having been nominated as ex-officio Members of Council to represent the Branches, it was proposed by A. C. Hartley and seconded by D. L. Samuel. This was carried without dissent :

S. A. Berridge	*Fawley Branch*
W. H. Davies	*London Branch*
G. M. Davies	*Northern Branch*
W. M. Stirling	*Scottish Branch*
J. R. Moore	*South-Eastern Branch*
A. S. Brooman	*Stanlow Branch*

MEMBERS ELECTED OR TRANSFERRED

The list of Honorary Members, Honorary Fellows, Members, Fellows, Associate Members, Associate Fellows, and Student Members elected or transferred during the year 1954 was tabled for inspection.

REPORT OF COUNCIL

C. Chilvers, presenting the Report of the Council, said : The year 1954 has been one of steady progress, which is far better than a less permanent but spectacular advance.

The Institute was honoured in 1954 by the presence of H.R.H. the Duke of Gloucester at the Annual Dinner, and this was an extremely successful occasion. The Cadman Memorial lecture by C. A. P. Southwell was also a noteworthy success.

The Summer Meeting at Llandudno was attended by more than 150 members and their wives. Because of the World Petroleum Congress in Rome there is no Summer Meeting in 1955, but arrangements have been made for one in 1956 at Torquay.

The Economics and Operations Group, under the chairmanship of O. F. Thompson, has fully justified its formation.

The Engineering Committee has done very good work throughout the year. The Marketing Safety Code has been published and work on the refining and on the production codes has continued.

As regards Publications, Professor Garner relinquished the honorary editorship at the Annual General Meeting last year. He had served the Institute in that capacity for some years extremely successfully, particularly in the difficult period immediately after the war. The high standard which he set has been maintained fully by his successor, Dr E. B. Evans, and by D. L. Samuel, who succeeded Dr Evans as Honorary Associate Editor.

No Annual General Meeting would be complete without reference to the standardization work of the

Institute, which goes on steadily. The 14th edition of "Standard Methods" was published in 1954 as well as the first edition of the "IP Engine Test Methods for Rating Fuels." Further co-operation work with other standardizing bodies, and in particular the ASTM has continued.

Membership showed a net increase of 123 and since the end of the year has increased now to something over 3300.

The Council desires to record again the debt which it owes to the many members of the Institute who have assisted in the work of the various committees, sub-committees, panels and to those Member-Companies (and there are very many of them) who provide facilities for co-operative laboratory work, and who allow their staff to help the Institute on its very many committees.

The permanent staff of the Institute also have again contributed much to the success which the Institute had in 1954, and the Council is very glad to record its appreciation of all their services.

C. W. Wood proposed that the Annual Report of the Council for 1954 be received and adopted. Dr C. T. Barber seconded the proposal, which was carried unanimously.

ACCOUNTS

H. Hyams, presenting the Accounts for the year 1954, said: I would like, as chairman of the Finance Committee, to express regret that it is not possible for the Honorary Treasurer, G. H. Coxon, to present the accounts. I am glad to say, however, that the trip which he is making to Australia reflects the splendid recovery he has made.

Income from subscriptions from corporate members, and from Member-Companies, totalled £19,220 in 1954, compared with £18,741 in 1953, and income from this source has increased by £2000 in the last three years. Of the subscription income 45 per cent is from Member-Companies, and we are grateful to those 180 companies which continue to give this substantial support.

Our operating expenditure last year totalled £18,920, of which £11,557 went on salaries and pensions. That is about 33 per cent greater than in 1950, but is exceedingly reasonable when the expansion of the Institute's work and the higher wages and salaries paid generally in industry are taken into account.

The balance of expenditure of £7360 compared with about £7000 in 1953. The major items included in this sum were just over £3000 for rent, cleaning, lighting, etc.; £2300 on printing, postages, stationery, telephones, travelling; £600 towards the cost of operating our branches at home and overseas; and about £480 meeting expenses.

A special word is necessary in respect of the Publications Account. The hard and meritorious work put in by the Publications Committee and its sub-committees, not only in producing a number of publications which were financially successful, but also in the issue of the *Journal* and the *Review* in their new size and which yielded so much revenue by way of advertisements, are all substantial contributing factors to the healthy state of our finances. I am sure we are all thankful to Dr E. B. Evans and his co-workers, and to D. A. Hough, George Sell, and E. W. Noble, our advertising manager, for these achievements. Members should know that were it not for the happy results of the labours of those to whom I have referred, it would not be possible to supply the increased size and improved *Journal* and *Review* at the present membership subscription rates.

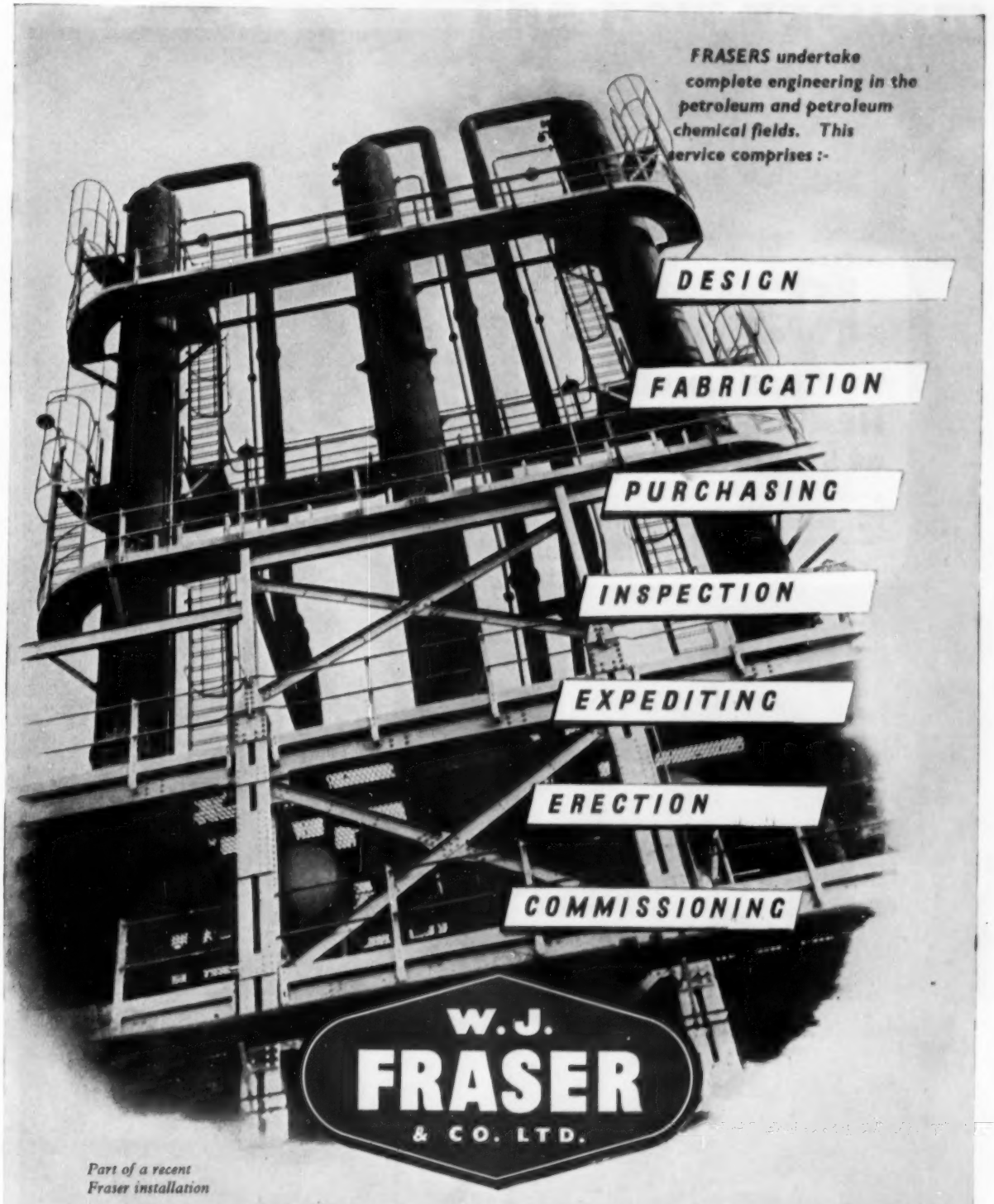
It is also worth occasionally reminding members, when presenting these annual accounts, that our handling of monies is not limited to the day-to-day activities of the Institute. We have a Research Committee and a Hydrocarbon Research Group, which receives from its members some £8000 a year, this money being dispensed by way of grants for research work at various universities and colleges. Our Benevolent Fund possesses some £3000, from which grants are made in deserving cases. Manson House is also the Head Office of the World Petroleum Congress, and the funds of the Permanent Council of that Congress are kept by us. Lt.-Col. Auld is Honorary Treasurer to the Permanent Council.

The surplus in our 1954 Revenue Account was £5833. This is £456 more than in 1953. We were therefore able to invest a further £4000 last year, and I am hopeful that we shall be able to do something similar this year. Our reserves, therefore, continue to make steady and sure progress, and this in turn should, I am sure, lead to further developments in the Institute's work, both in the interests of our members and of the industry.

It was proposed by A. J. Ruthven-Murray and seconded by W. H. Davies that the Accounts be adopted. This was carried unanimously.

AUDITORS

H. Hyams proposed and D. L. Samuel seconded the appointment of Messrs Smith and Williamson as auditors for 1955 at a remuneration to be fixed by the Council. This was approved.



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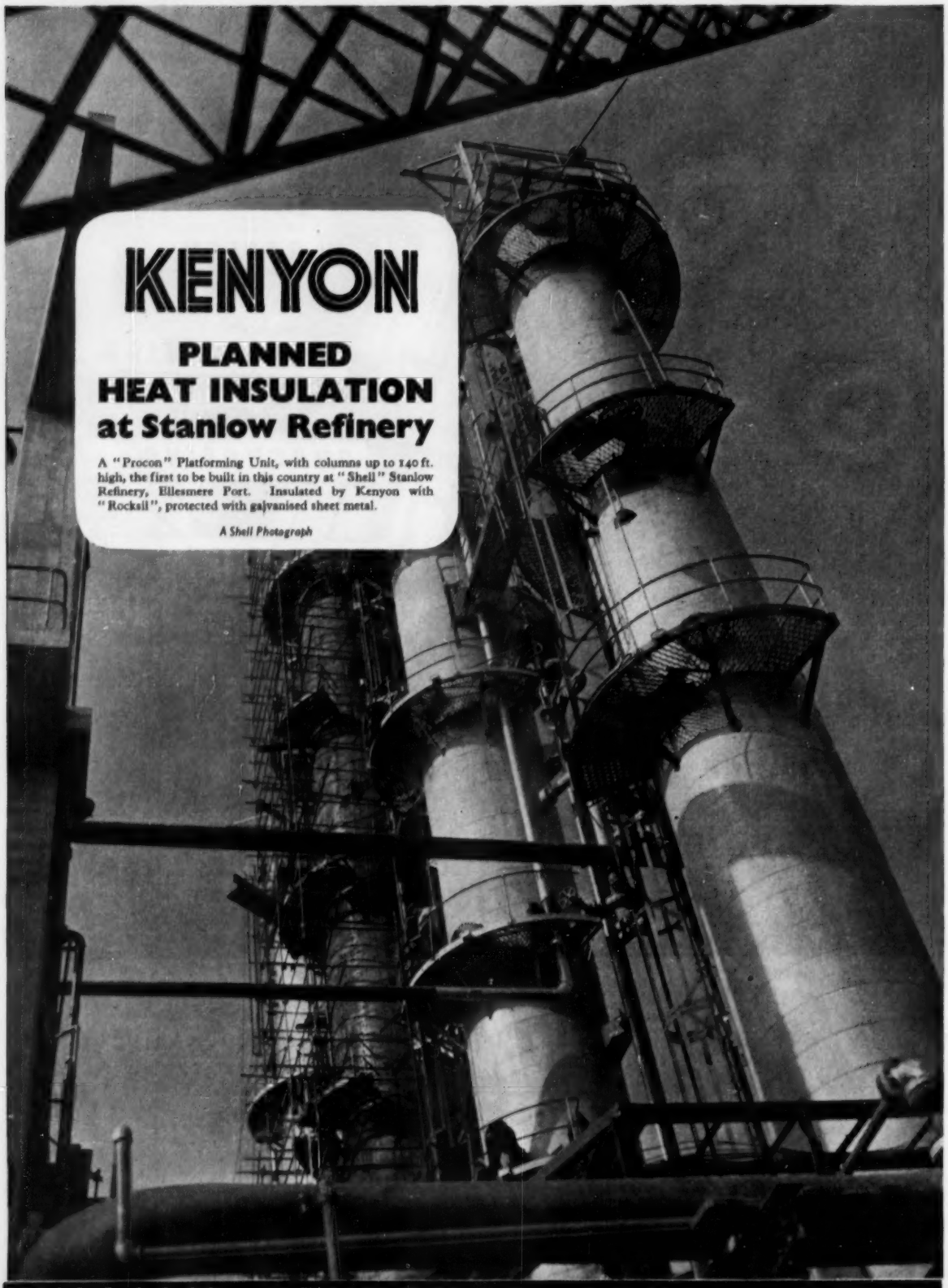

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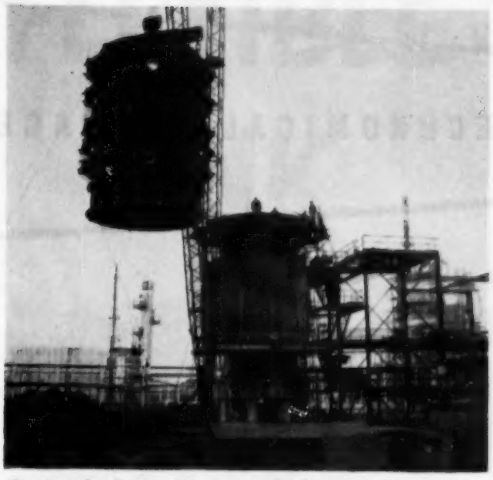
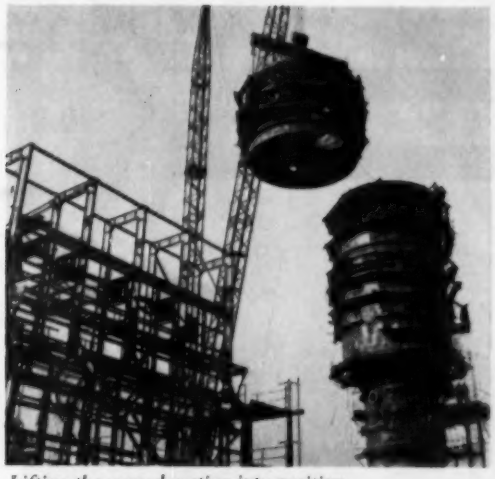
The new vacuum pipestill unit at Fawley

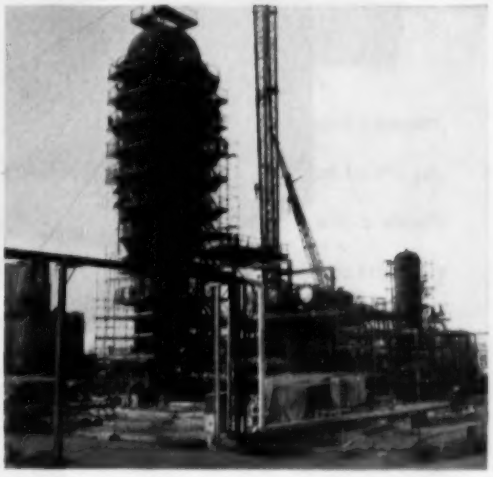


Putting the first section on to the base



Lifting the second section into position

Preparing to raise the domed head



The final assembly in progress

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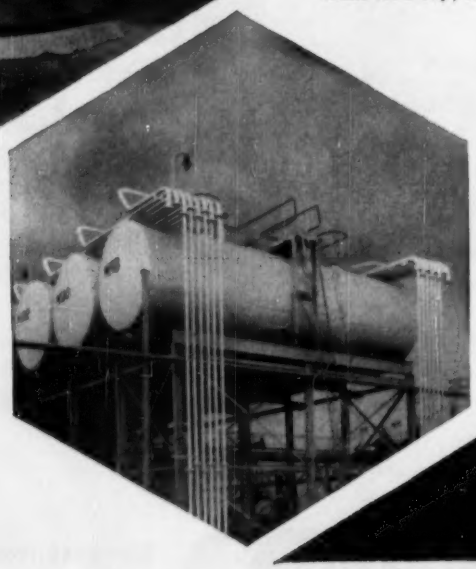

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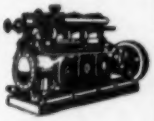

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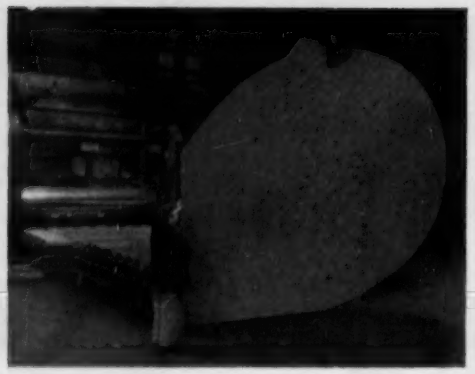

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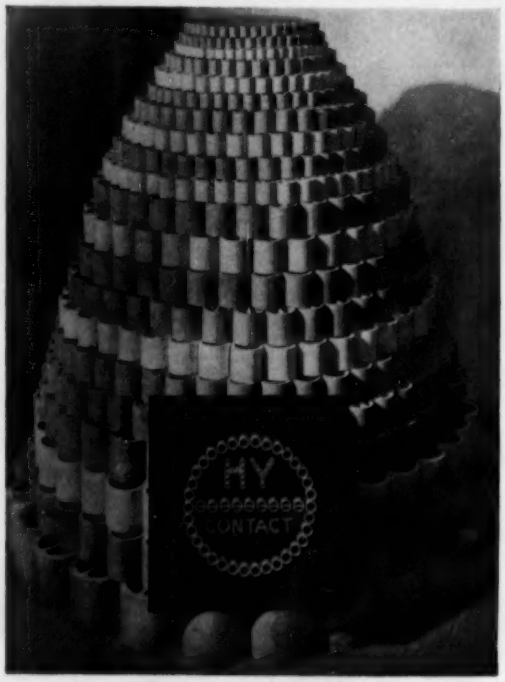

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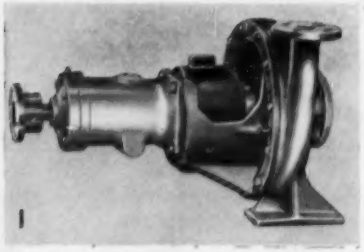

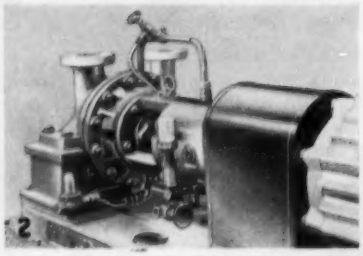

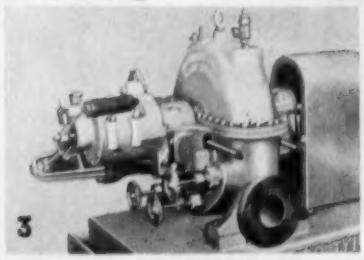

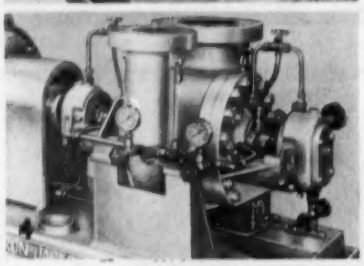

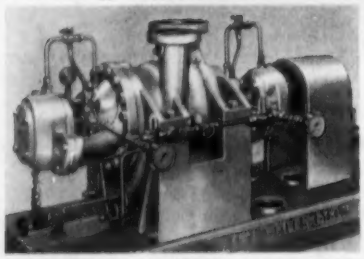

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The lightest reinforced hoses on the market–

COMPOFLEX FEATHERWEIGHT

For extreme lightness and ease of handling there's nothing to compare with this all-purpose flexible which is one of a new range of suction and delivery hoses based on Compoflex principles. New combinations of synthetic materials have been used for the walls, together with an entirely new method of bonding and curing by heat treatment.

As a result, the FEATHERWEIGHT combines unusual lightness, great strength and flexibility, with improved durability and crush-resistance. It can also handle a wider variety of chemicals, including pure Benzoles, petroleum and oils, and is the ideal hose for road, rail and similar tank haulage work.

The FEATHERWEIGHT, which costs the same as the well-known standard OILMASTER, can be supplied in lengths up to 30 ft. with 1-in. to 4-in. bores. Alternative linings can be supplied at extra cost for special purposes.

For corrosive and abrasive conditions. Two new SMOOTH BORE hoses are available. The FLOWMASTER has a completely embedded spiral so that the metal cannot be attacked by the flowant. In the BANTAM, the spiral is flush with the inner surface, giving the lightest possible smooth bore hose.

For extra-heavy duty. Still stronger and tougher but lightweight Bargemaster and Jettymaster hoses are recommended for barge, ocean terminal and similar work. (6" and 8" bores).

TANK HAULAGE OPERATORS SAY:–

☆ IT'S HALF THE WEIGHT OF ANY OTHER HOSE

☆ IT'S EASY TO HANDLE

☆ IT'S TOUGH AND FLEXIBLE

If you have a 'flexible' problem, you'll find the answer at Compoflex

Typical Weights and Working Pressures

I.d.	Weight per foot	Bend Radius	Working Pressure
Inches	Lbs.	Inches	Lbs. P.S.I.
2"	·9	3½"	200
2½"	1·37	5½"	175
3"	1·6	6"	175

THE FEATHERWEIGHT

Produced by **COMPOFLEX**

COMPANY LIMITED

DURAX

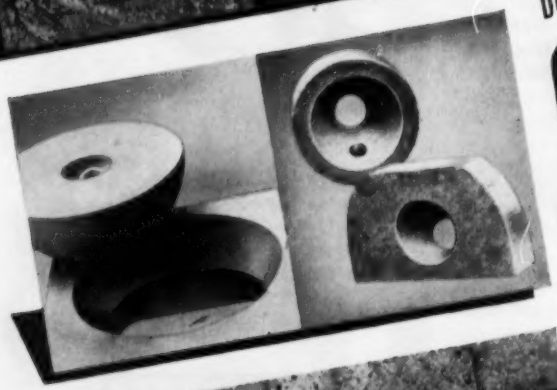
THE INDISPENSABLE REFRACTORY!

- ★ RAMMING PATCHING & MONOLITHIC LININGS
- ★ SPECIAL & EMERGENCY SHAPES · COMPLETE LININGS
- ★ THIN SOUND & STRONG JOINTING
- ★ PNEUMATIC GUN CEMENT LININGS

DURAX No 1

PLASTIC FIREBRICK COMPOSITION

Supplied ready mixed for immediate use. Suitable for rammed linings and patching existing Durax No. 1 or firebrick linings. Service temperature range 1300/1650°C.



DURAX No 2

REFRACTORY CONCRETE

For casting in situ and making special shapes. Supplied dry. Special characteristics include—rapid setting as hard as firebrick: pours into position: no permanent volume change: little tendency to spall. Maximum service temperature 1300°C.

DURAX No 3

REFRACTORY CEMENT

A finely ground air setting cement for jointing all types of firebricks. Supplied dry. Special characteristics include—produces thin and strong joints: negligible shrinkage: highly refractory: economical in use. Maximum service temperature 1650°C.

DURAX No 5

GUNNING OR PLASTERING CEMENT

A cement designed for application with a pneumatic gun. Alternatively it may be plastered into position. Durax No. 5 has little rebound loss when applied by gun to Catalytic Regenerators and forms a dense tough lining with a maximum service temperature of 1300°C.

★ *Fully descriptive literature on all of these grades of Durax is available on request*

GENERAL REFRACTORIES LTD

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